CLINICAL ATLAS

VARIATIONS OF THE BONES OF THE HAND AND FOOT

THOMAS DWIGHT

A CLINICAL ATLAS

VARIATIONS

OF THE BONES OF

THE HANDS AND FEET

BY

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PREFACE

THE constantly increasing use of the X-ray has shown that the study of variations is not a scientific fad but a matter of very great practical importance. Not only are the ordinary variations (still but little known to the surgeon) constantly appearing, but very uncommon ones are occasionally seen. In fact the number of hands and feet examined by the X-ray is so much greater than that of those seen *post mortem* by anatomists, that it is not surprising that variations thought excessively rare should repeatedly be brought to light.

For many years I have devoted myself to the study of variations in man, especially to those of the spine and of the bones of the hand and foot. The importance of these in the practice of surgery becomes clearer day by day. This Atlas has been prepared for the use of the practitioner. Some variations are discussed which are of interest to the orthopædist, but attention has been given chiefly to those which may be expected to appear in skiagraphs taken after an injury and which may suggest a fracture to the unwary.

As the work is meant first of all to be practical, scientific discussion has been reduced to a minimum. It is necessary, however, to give the plan of the hand and foot according to the views of the lamented Professor Pfitzner, whose name will live as that of the pioneer in this line of research. Although I do not accept his theory without reserve, and disagree with him on some points, I find it very useful as a working hypothesis.

Every single bone specimen shown in these photographs was observed by me and belongs to the *Harvard Medical School*. Almost all of them are in the *Warren Museum*. I wish to acknowledge the courtesy of the authorities of the *Journal of the American Medical Association* and of the *Anatomischer Anzeiger* in allowing the reappearance of illustrations which have been published in their pages.

The skiagraphs were taken at the *Massachusetts General Hospital*. I have much appreciated the hospitality of that institution by which I have been able to examine many hundred negatives and to publish such as I wished. I cannot express too strongly my indebtedness to Mr. Walter J. Dodd, the head of the X-ray department, for his unfailing patience, his valuable help and constant interest.

THOMAS DWIGHT.

HARVARD MEDICAL SCHOOL, October, 1907.

ILLUSTRATIONS

LIST OF FIGURES OF HANDS.

LIST OF FIGURES OF FEET.

LIST OF FIGURES OF FEET (*Continued*).

INTRODUCTION

It is still customary to teach that the wrist consists of eight bones and the ankle of seven, the homologies of which are not altogether so clear as could be wished. Nevertheless it is well known that at an early stage the wrist and ankle of the human embryo contain many centres indicating bones which during development either disappear utterly or fuse with others, of which they form more or less important parts. Thus, though usually undistinguishable, they may exceptionally persist either as isolated (supernumerary) bones, or as very evident processes on some of the permanent elements. The arrangement of these centres in the præcartilaginous stage is supposed to be on a flipper-like plan after the fashion of the ancient saurians. Some centres are easily identified as representing elements familiar to the student of comparative anatomy; others are of uncertain significance. Let us now follow a little more in detail what actually occurs in the human wrist. The cells of the undifferentiated tissue arrange themselves in groups which represent possible bones. Histological changes occur by which certain of these groups become cartilaginous centres. Not all of them, however, go so far. Some lose their identity very soon. Others, having become cartilaginous, may disappear, leaving no trace behind them, or they may join themselves to other centres, thus forming a composite bone. On the other hand, they may pursue an exceptional course and persist as separate bones. But to return to the story of development: after these centres, or some of them, have become cartilaginous, the tissue between them breaks down so as to form the synovial cavities between the bones, while in other places fibrous tissue appears, forming ligaments, or so-called fibro-cartilage, connecting them. It is to be noted that some of these centres are found in perhaps 79 per cent. of the embryonic hands. Now, as to the fate of a group of cells of the cartilaginous era which, instead of disappearing as usual, for some reason or other preserves its individuality more or less perfectly. It may become an absolutely free bone. Such a one may be connected with its neighbours by true joints on one or more surfaces, or it may have merely a ligamentous attachment. It may become closely connected with one or more of its neighbours by fibro-cartilage and present the characteristic surface that is found on bones so connected. Again it may be actually fused with a neighbour but so clearly marked off on the surface that there is no question as to its identity; and finally it may be so intimately fused and so shorn of its own characteristics as to leave its nature

very problematical. It is, moreover, to be noted that one of these exceptional elements may be connected in these various degrees of intimacy with no particular bone but with any one of its neighbours, thereby very considerably modifying their shape. As an illustration take what is commonly known as the styloid process of the third metacarpal. It is found as a separate element in a large proportion of embryos. It may persist as a separate bone throughout life, with synovial surfaces; or it may, as is usually the case, fuse with the third metacarpal, forming the so-called styloid process. It may, however, join the os magnum, and more rarely the trapezoid. Finally, and this is important, while joining one bone, let us say the metacarpal, by true bony union, the surface towards the os magnum, instead of the articular covering which is usual, may be connected to that bone wholly or in part by fibrous cartilage. This union may indeed be so close that before maceration the bones may be thought to be continuous. In fact, fusion with both bones may occur. Moreover, such an element, before fusing with another bone, may wander a little from its original position.

Sesamoid bones deserve in this connection very particular mention. In the first place, a sesamoid bone under normal circumstances is laid down in cartilage as distinctly as any other bone and deserves to be considered a regular and typical part of the skeleton. Bones sometimes called sesamoids are beyond question bones to be considered as typical parts of the wrist and ankle, as, for instance, the *tibiale externum* of comparative anatomy, but more commonly known among us as the sesamoid in the tendon of the tibialis posticus. We shall see later that it is occasionally fused or closely united to the scaphoid. What is a bone of the skeleton in certain animals may be merely a swelling in a tendon in others, apparently represented in some cases merely by an accumulation of fibrous tissue; or again it may be a well-developed bone. The sesamoids of the metacarpo-phalangeal joints and those of the interphalangeal joints and the corresponding ones in the foot are much more numerous in the fœtus than in the adult. In some carnivora and other animals there are also dorsal sesamoids of which but very few representatives have been found in the human being. At least most sesamoids have no particular function.

It is evident from what has been said that the *first class* of variations is due to the persistence of elements apparently having a place in the plan of the wrist and ankle which usually disappear, thereby, if free, increasing the number of bones. Now, in the *second class* the converse occurs. There may be too few bones, from the union of pieces usually distinct. It has been said that, in the early cartilaginous stage when the joint cavities appear, fibrous tissue is developed at certain places. It is easy to conceive that instead of this coming to pass two future bones may be connected by cartilage which later turns into bone. The articular cavity may not appear or cartilage may develop instead of fibrous

tissue. Still another cause is assigned by Pfitzner,—namely, that an occasional bone which usually does not appear, or at most is represented by a tubercle on another bone, may be connected either by bony tissue or by fibro-cartilage with two neighbouring bones which it thus unites. I see no difficulty in accepting all these explanations. There is a *third class* of variations absolutely different, in theory at least, from those already mentioned. It includes cases of large processes in places where there is normally either a small one or none at all. Among these are some which may reasonably be considered pathological or at least regarded with suspicion, but which nevertheless are found at certain definite places and present tolerably constant features. Be the explanation what it may, these deserve to be recognized. Finally, it might be said that there is a *fourth class* of variations, consisting in departure from the ordinary relations of bones. This can be called a class only because this difference of relation is the feature on which we fix our attention. It is true that this may be of great practical significance, but it is clear that this difference of relation (putting aside cases in which one bone is exceptionally large or small) must depend on some of the foregoing causes and is really the result of a variation of one of the three true classes.

For the understanding of the occasional bones it is necessary to give Pfitzner's plan of the hand and foot. These are considered separately and no attempt is made to discuss the homologies of the limbs. Both hand and foot, however, consist theoretically of a number of longitudinal rays (the question whether there be five or seven need not be opened), the elements of which are also arranged in transverse rows. Pfitzner indeed seems to think that the longitudinal arrangement is interrupted at the wrist, but this also we pass over. While I think that Pfitzner's[1] theory should be adopted as a working hypothesis, there is one objection to it. In his discussion of certain doubtful elements in his work he points out that element A, for instance, cannot be element B because the latter is clearly present. Now, in point of fact, I think that I have several times seen the same element represented by two swellings on adjacent bones in the

[1] Pfitzner occupies a rank by himself among students of variations of hands and feet. I shall have to refer to him constantly. To avoid endless repetition I give here the references once for all.

I. *Beiträge zur Kenntniss des menschlichen Extremitätenskelets. Schwalbe's Morphologische Arbeiten*, Band i, 1892. This paper deals with general principles and certain measurements, which latter are not discussed in this work.

II. *Die Sesambeine des menschlichen Körpers. Ditto.* Devoted entirely to sesamoids.

III. *Die Variation in Aufbau des Handskelets. Ditto*, Band iv, 1895. This is a very thorough discussion of the variations of the hand.

IV. *Die Variation in Aufbau des Fusskelets. Ditto*, Band vi, 1896. A very thorough discussion of the variations of the foot. Consult the sections on the individual bones in this paper.

same wrist. The error consists in holding that a certain permanent condition must always be brought about by the same element. Now, studies in variation show clearly that when there is an initial error or deviation in the course of development there is an effort in the organism to reproduce the normal condition as nearly as circumstances will permit, and this may be accomplished by changes in other parts.

Pfitzner has received most valuable support from the embryological work of Thilenius,[1] who looked for elements in the earlier embryonic carpus and has shown that those which appear very rarely in the adult may be found with great regularity in the first stages of development. His nomenclature and plan of the carpus are not quite the same as Pfitzner's.

V. and VI. *Die morphologischen Elemente des menschlichen Handskelets. Allgemeiner Theil, Zeitschrift für Morphologie und Anthropologie*, Band ii, 1900, S. 77. Specieller Theil, *ditto*, S. 365. In the former of these papers there is a general discussion of the question as applied to the hand. On page 152 a list of the elements which he recognizes is begun; on pages 156 and 157 are the diagrams of the carpus according to his ideas. These diagrams supersede those of a previous paper.

In the special part he gives a description of 1456 hands and goes through the variations again. Thus, in referring to any particular variation of the hand it is best to look it up in this article, and if necessary refer back to the former one of 1895. In this paper he gives also a description of the normal bones.

[1] The following papers by Thilenius should be studied by those interested in the scientific side of the question.

Zur Entwickelungsgeschichte der Sesambeine der menschlichen Hand. Schwalbe's Morph. Arbeiten, Band v, 1895.

Untersuchungen über die Morphologische Bedeutung accessorischer Elemente am menschlichen Carpus. Morph. Arbeit., Band v.

Accessorische und echte Skeletstucke. Anat. Anzeiger, Band xiii.

VARIATIONS
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THE HAND.

PFITZNER'S plan of the hand is as follows: First, an ANTIBRACHIAL row composed of two bones very rarely met with in the adult, the *triangulare* and the *secondary pisiform*. Second, the PROXIMAL row, consisting of the *radial* and *ulnar scaphoids*, which normally form the greater part of the scaphoid, the *semilunar*, the *radial* and the *ulnar cuneiform*, which, however, have never been seen separate, and the *pisiform*; the CENTRAL row consisting of several elements none of which normally persists as a separate bone; they are the *radiale externum* joining the outer side of the tuberosity of the scaphoid, the *epitrapezium* a very rare and unimportant little ossicle on the dorsum of the trapezium, the *centrale* which Pfitzner divides into a dorsal and a palmar element, the latter of which may be left out of practical consideration, the *epilunatum* which normally forms the tip of the dorsal point of the semilunar, the *hypolunatum* in a corresponding relation to the palmar point, the *epipyramis* forming the radial angle on the dorsal surface of the *cuneiform*, and the *ulnare externum* on the dorsal aspect of the cuneiform at the edge of the hand near or against the unciform. The DISTAL row contains the *trapezium*, the *trapezoid*, or rather its palmar half, the *metastyloid* a small ossicle at the tip of the styloid of the third metacarpal between the trapezoid and the os magnum, the *capitatum proprium* which forms the proximal and the chief part of the *os magnum*, and the *unciform*. The CARPO-METACARPAL row consists of a number of bones none of which is seen in a normal hand; the *paratrapezium* constituting the outer angle of the trapezium, the *prætrapezium* on the palmar aspect of the tuberosity of the trapezium, the *trapezium secundarium*, the ulnar distal angle of the trapezium, the *secondary trapezoid* on the dorsum between trapezoid, trapezium and second metacarpal, the *epitrapezoid* which is essentially the greater part of the dorsum of the trapezoid, the *parastyloid* forming the dorsal ulnar projection of the base

of the second metacarpal, the *styloid* being the element which usually forms the styloid process of the third metacarpal, the *subcapitatum* forming the swelling in the palm on the distal half of the os magnum, the *capitatum secundarium* forming the dorsal distal portion on the ulnar side of the os magnum, *Gruber's ossicle* a small element in the palm at the point of junction of the lines separating the third and fourth metacarpals and the os magnum and unciform, the *os hamuli* which is the unciform process of the bone of that name, the bone of *Vesalius* or *Vesalianum*, forming the tip of the tuberosity of the fifth metacarpal.

VARIATIONS AND ADDITIONAL BONES.

It is proposed in discussing the variations of the hand and foot to take the normal bones in order and to describe the occasional bones at the same time as the normal elements with which they are most intimately associated. Thus the *styloid*, which belongs in the carpo-metacarpal row, shall be considered with the third metacarpal of which it is normally the styloid process, and the *radiale externum*, instead of being considered with the central row, none of the elements of which normally appears as a separate bone, shall be treated of with the scaphoid of which it forms the extreme radial projection. This course will make the matter more simple. One of the bones of the antibrachial row, the *triangulare*, must, however, be taken by itself.

The *triangulare* is very common in the early embryo, having been found by Thilenius [1] in 65 per cent. in the second month; but it is very rare in the adult. It is situated theoretically between the radius and ulna on one side and the semilunar and cuneiform on the other, on the distal surface of the so-called triangular cartilage, which according to Pfitzner[2] is really nothing but fibrous tissue. I have seen a minute ossification in this situation in several skiagraphs. I have once seen a small ossicle projecting from the distal end of the head of the ulna near the base of the styloid process which may be supposed to be this element. It may wander towards and beyond the tip of the styloid process of that bone. Pfitzner figured an ulna with the tip of the styloid separate from the rest. In figure 1 is given a skiagraph of a similar occurrence, though, as is stated more fully in the description, there had been an injury of the hand. There is some danger of confounding the *triangulare* with the far rarer *secondary pisiform*, of which later, when the bone is near the tip of the styloid process of the ulna, but the practical point is this,—namely, that a small ossicle may be found on (or below) the distal surface of the triangular cartilage, and also beyond the tip of the styloid process of the ulna, or on its radial side, which by its out-

[1] Schwalbe's Morpholog. Arbeiten, Bd. v, 1896.

[2] Some cartilage cells have been found in it.

line can easily be distinguished from a recent fracture. Among uncommon relations of the bones may be mentioned a single case, observed by Pfitzner, of the articulation of the styloid process of the ulna with both the cuneiform and the pisiform, after the fashion commonly found in mammals.

The *scaphoid*. This bone, according to the plan we are following, is composed of two chief parts, a radial and an ulnar scaphoid, and of certain accessory ones, namely a radiale externum and a centrale. The epilunatum moreover is occasionally fused with it. The scaphoid presents a great range of variations of size and shape as well as of internal structure, which have their importance in the discussion of the burning question of subdivided scaphoid. There is little exaggeration in saying that before the X-ray practically nothing had been heard of fracture of the scaphoid. The bone is first laid down as a single group of cells. Ossification begins very late, about the sixth year, apparently usually by a single centre, though two have been described. There is no question, however, that the bone may develop in two nearly equal parts. A double cartilaginous centre has been seen by v. Bardeleben.[1] Thilenius[2] has found in an embryo conclusive signs of the union of two parts having already occurred. I have had the fortune to find the bone subdivided at birth. There are cases of partial division in which the two pieces have almost lost their individuality but in which the concave surface shows a deep cut just below the dorsum, or a fine fissure crossing it. The latter may be represented by a line of nutrient foramina. It is not rare to find a large cavity near the middle of the scaphoid which may be both the consequence of an early subdivision and also a predisposition to fracture.

The study of thin sections of the scaphoid as well as of skiagraphs shows very great differences in the internal structure of the bone. Often the sections show a denser structure at the proximal end, the network of trabeculæ being of what I have called the round-meshed pattern such as is found in the head of the femur, which is followed by a distinctly weaker region at the middle, and by a denser structure chiefly of parallel plates at the distal end. This latter denser region is not usually as dense as the proximal one. X-ray plates show much variation and are often difficult to interpret. Sometimes the internal structure consists of beautifully distinct trabeculæ no closer together at one place than at another, while again the greatest density is in the distal radial half. Often the figure is crossed by a curved line with its convexity to the ulnar side probably caused by the swelling of the palmar part of the distal end.

In a considerable proportion of scaphoids there are signs of an incomplete division, or, more accurately, of an incomplete union of two originally

[1] Jenaische Zeitschrift, Bd. xix. S. 149.

[2] Morpholog. Arbeiten, Bd. v, S. 475.

distinct elements. In a comparatively small number of adult hands the scaphoid is found completely divided. As Pfitzner has shown, the line of division runs obliquely from near the outer end of the articular surface for the radius to about the middle of the concavity for the head of the os magnum. Thus the bone is divided into a somewhat larger radial element distally situated and bearing the trapezium and trapezoid, and into an ulnar element placed beside the semilunar. That this division may occur without fracture is absolutely undeniable. I have found the bone in two pieces in the right hand of a white man of sixty-one. The same hand had an extra bone of difficult interpretation (probably an epipyramis) on the dorsal aspect of the cuneiform. The left scaphoid was in one piece, and there was a free epilunatum in that hand. The two pieces were in perfect apposition, and the bone showed no sign of injury. After the bone had been drawn and a skiagraph made from it, I had it cut into thin slices which showed a strip of cartilage between the pieces. An expert who examined it at my request agreed with me that the pieces were in their original relations. Figure 4 is a skiagraph of a fractured radius. The erroneous diagnosis of a fracture of the scaphoid had probably been added after the plate had been made. One has only to compare the articular surfaces of the two pieces of the scaphoid with those of other bones in the same wrist, and to contrast their appearance with that of the undoubted fracture of the radius to know that this is a case of subdivided scaphoid. In some specimens the surfaces of the two pieces are held together by degenerated fibro-cartilage or articular cartilage which had been pretty much worn away, but which presented a very different appearance from that of the surface of a fracture.

It must be frankly admitted that the great majority of specimens of subdivided scaphoid have a very pathological appearance. Pfitzner is very nearly at the point of denying the occurrence of fracture in any of these cases. I think this is going too far, for the history of lesion is often very precise and I do not doubt that an undivided scaphoid may be broken. Pfitzner argues very convincingly that a subdivided scaphoid is not a good mechanical arrangement, that the pieces playing one on the other become displaced, that the cartilage degenerates, the surfaces become eburnated and finally signs of inflammation appear marked by the formation of irregular pieces of bone. To this I would add that a subdivided scaphoid is no charm against the accidents to which all are liable. On the contrary it makes a slight injury the more serious, as such a scaphoid may be lacerated by violence which would not have broken a normal bone. I am far from questioning the diagnosis in many cases of fracture of the scaphoid. I do not deny that a normal bone may be broken; but I strongly suspect that in most cases called fractures there was a subdivided bone to begin with. There are some very pathological specimens in which the bone consists

of at least three pieces. Whether these are due to pathological causes during development or to degenerative changes probably following a lesion I must leave undetermined.[1]

The *radiale externum* (a term used in comparative anatomy) is the end of the tubercle of the scaphoid. I have seen it both in X-rays and in specimens, but I have always found either a history of lesion with the former or signs of inflammation with the latter. Pfitzner, however, figures cases which show nothing pathological. Although very generally found among mammals, it is excessively rare in man.

The centrale, which it is convenient to consider with the scaphoid, is almost constant as a group of cells in the early embryo, and is normal as high in the scale as the ourang, but it is one of the most uncommon bones to find distinct in the adult. For all practical purposes it is a dorsal element. Its usual fate is to fuse with the scaphoid, but it may disappear completely or fuse with the os magnum, and perhaps with the trapezoid. It is found relatively often in cases of subdivided scaphoid. When it disappears completely, its place being taken by fibrous tissue, skiagraphs show a very striking void between the os magnum and the distal part of the scaphoid. Sometimes they show the *centrale* projecting into this space from the latter bone. Sometimes it is partially marked off by a furrow in the concave surface of the scaphoid. The *centrale* has been seen in more than one piece, but I regard such specimens with suspicion. (For rare cases of fusion of the *epilunatum* with the scaphoid see the next bone.)

The semilunar. This bone, which gets its name from its shape in profile, has two elements (besides its own centre) more or less completely absorbed into it at the tips of the horns. The dorsal one is the *epilunatum*, the palmar one the *hypolunatum*. The *epilunatum* is very frequently clearly marked off by a line, so that it appears as a knob on the dorsal horn at its radial side. It occasionally is found separate, but the largest specimens I have seen have a very pathological look. It may join the scaphoid at its dorsal ulnar angle, or it may be seen as a projection on the dorsal distal border near the same place. The semilunar as a whole varies considerably in breadth, but the matter is of no practical importance. I have seen the semilunar divided almost symmetrically into a dorsal and a ventral half. How is this to be explained? It might be a fracture, and Pfitzner, who has seen it in a hand with a broken fifth metacarpal, inclines to think so; but in my case there was no sign of violence. There is no evidence offered by embryology nor by comparative anatomy that the semilunar

[1] Consult Wolff's discussion as to whether the bipartite and tripartite scaphoid is the result of a fracture, with his report of an instance of congenital division in both hands. Deutsche Zeitschrift für Chirurgie, Bd. lxx, S. 254, 1903.

consists of two elements.[1] I incline to explain it as an overdevelopment of the epilunatum and an underdevelopment of the chief bone. A large nutrient foramen entering at the radial side and expanding into a cavity may be a source of weakness. The *hypolunatum* on the palmar aspect is rare and of little practical importance.

The cuneiform. The variations of this bone are not very striking. They are of two kinds: first, a variation in the transverse diameter by which we have long and short bones, and, second, a tendency to subdivision by which there are more or less clearly marked off a radial and an ulnar element just as in the scaphoid. These however have never been seen separate nor do they appear as two separate centres. I am not inclined to follow Pfitzner in accepting them. He points out in further support of his view that besides the occasional appearance of a line of separation the two parts have very different characteristics, the radial being always about the same, while differences in the length of the bone are due entirely to the ulnar element. The *epipyramis* is a very rare bone which, when separate, appears on the dorsum between the semilunar, cuneiform and the unciform. It would naturally be mistaken for a fracture. Usually no trace of this element is to be found, but it may appear as a marking off of the dorsal distal radial angle of the cuneiform; hence it is mentioned with that bone. I have seen one case; but a doubtful one.

The ulnare externum, also a very rare element, is for the same reason considered with the cuneiform. It is a dorsal element on the ulnar side of the hand situated between the tuberosity of the fifth metacarpal, the unciform, and the cuneiform. It may be free or it may be fused with the cuneiform. I have seen a case in an X-ray which strongly suggested it, but the history of an old lesion and some disability in the use of the hand did not justify me in accepting it. There are two or three specimens in the Harvard collection.

The pisiform and the secondary pisiform. The former of these or the *pisiform* proper is a most irregular bone, not only in size and shape, but in position, appearing sometimes more proximally, sometimes more distally situated than usual. Also it seems sometimes to project very strongly beyond the ulnar side of the hand while normally it is wholly on the palmar side. These peculiarities are all more or less exaggerated in X-ray views. The *secondary pisiform* already alluded to is found very rarely laid down as a separated centre in the embryo. Two centres of ossification, one distal to the other, have been seen by Debierre[2] in a girl of eleven and a boy of twelve. It occasionally appears as

[1] There is an unconfirmed statement by Serres that there are two centres of ossification, near together but quite distinct.

[2] Contribution a l'étude de l'Ossification et de l'Homotypie des pièces du carpe et du tarse chez l'homme. Journal de l'Anatomie et de la Physiologie, Tome 22, 1886.

a proximal prolongation of the pisiform, sometimes making a second swelling. I have one hand in which the pisiform has every appearance of having lost this element. There is a proximal surface overhung by the palmar projection of the bone which has the character of a surface to which a bone has been fastened by non-articular cartilage. Though the case must be doubtful I strongly incline to think that in this instance this element was really present and lost before I examined the specimen. This element should (I think) be shown by lateral X-ray views.

The trapezium presents very little of interest. Perhaps the most important feature is the degree of development of the ridge which, usually small, is occasionally very prominent, suggesting the hook of the unciform. The distal end of this may be represented by a small separate bone, the *prætrapezium*. I have a pair of hands showing it on both sides. It not very rarely appears as a knob on the ridge. Pfitzner long doubted whether to consider the angle of the trapezium between the bases of the first and second metacarpals as a true element. He has decided to do so and has named it the *trapezium secundarium*. It is excessively uncommon, except under very pathological conditions, in which I have seen hints of it several times and I think once at least have found it distinct. Usually I have found it with a distortion of the metacarpal of the thumb and with a flattening of the socket. I have seen no case myself that was not pathological. It is worth while, however, to recognize the possibility of a distinct bone in this place under such conditions.

The *epitrapezium*, on the dorsal side next to the scaphoid, has once been seen separate by Zuckerkandl. I have seen a prominent projection on the dorsum which may be explained as this element. It is apparently not infrequent in anthropoids.

The *paratrapezium*, forming the outer distal angle, has also been seen separate only once. The observation is by Cuyer.[1]

The *trapezoid* has been found a few times divided into a dorsal and a palmar half, the latter reaching the dorsum at the radial side. This bone shows so badly in the ordinary X-ray view, owing to the position of the trapezium overlapping it, that its study leads to little of practical importance. Sometimes the *styloid*, of which more later, is fused with it.

The *os magnum* shows considerable minor variations of shape and size. Perhaps the most striking is the change of the distal dorsal border from oblique to transverse when the styloid (discussed with the third metacarpal) is fused with it. There is also considerable variation on its radial side in the depth of the fossa occupied by the centrale when it is present as a distinct bone or as an

[1] Bull. Soc. d'Anthropol. Paris, 1887, p. 303.

offshoot of the scaphoid. The *os magnum* consists theoretically of three bones: the *proprium* which is the main bone, the *capitatum secundarium* which is the distal ulnar dorsal angle, and the *subcapitatum* which is the swelling on the distal end of the palmar surface. This last is a monument to Pfitzner. He had described the three parts of the os magnum as marked off on several specimens, but he never found a subdivided magnum himself. The *capitatum secundarium* is not rarely indicated on the dorsum. It has been seen as a separate bone only twice, once by Gruber[1] of St. Petersburg and once by Lamb[2] of Washington. Undoubtedly it will be shown sometime by the X-ray and will suggest a fracture, provided always that the focus be such as to show the dorsum, which is not usually the case. Some bones show it and the styloid as two knobs. The swelling on the palmar side made by the *subcapitatum* varies very much in different bones and consequently in X-rays. Sometimes they show the outline very clearly. The author[3] is the only one who has had the fortune to find this element separate. He observed it after Pfitzner's death on both hands of one body. Very certainly there is no possibility of a fracture; but the separate bone is considerably smaller than was to be expected. Probably the X-ray at the proper focus would show this bone, just as it does the swelling which normally represents it, but it is hardly conceivable that it should show it as a distinct element.

Gruber's ossicle, excessively rare, of which I have no personal knowledge, is a little pyramid with the base on the palmar side of the hand and the apex plunging into the space between the third and fourth metacarpals and the os magnum and unciform.

The *unciform* is composed of two parts, which may have separate centres in the præcartilaginous stage, and also separate centres of ossification, the bone proper and the hamular process, *os hamuli*. As we are not working scientifically but practically, and as this is one of the greatest puzzles of the whole question, I shall leave explanations quite aside. The variations of the bone of practical importance are pretty nearly limited to the hook, which may be small or large, sometimes rather weak and triangular, when seen from the side, and again very long and square-cornered. Of most practical interest are the cases in which the hook is distinct. This may occur in such a way that the whole hook is separate and well-formed. This is easily explained by a separate centre for the hook, which Thilenius has observed; but there may be a small longitudinal ridge like the base of a hook and on this a free terminal piece, usually underdeveloped, or this terminal piece may be wanting. I have seen, I believe, all of these con-

[1] Mélanges Biol., vii, 1870.
[2] Washington Medical Annals, vol. iii, 1904.
[3] Anat. Anzeiger, Bd. xxiv, S. 253, 1904.

ditions in bones, but have never met with any convincing X-ray. A side view would suggest fracture.

There remain five bones of the carpus, four of which, the *secondary trapezoid*, the *parastyloid*, the *styloid*, and the *bone of Vesalius*, are in closest connection with the metacarpal bones and shall be considered with them; while the fifth, the *metastyloid*, shall be taken after the styloid.

The metacarpals. Apart from the variations depending on the bones just mentioned there is not much to say about the metacarpals. There is a long type and a short type; but the latter is the more important as sometimes the reduction in length is very considerable, amounting to at least half the ordinary length. Two or three fingers may be affected, the condition occurring in both hands, though without perfect symmetry. A remarkable case of shortening of the fifth metacarpal is mentioned in the section on fusion of bones. The human metacarpals ossify from a centre for the shaft and an epiphysis which is in the proximal end of the first metacarpal and in the distal end of the others. Exceptionally an epiphysis is found in the proximal end of those of the fingers. Whether it is a true epiphysis or has a very slender connection with the centre for the shaft may be disregarded, for it has all the outer appearance of a true epiphysis and seen by the X-ray might be mistaken for a fracture. That of the index finger seems to be the most common. I have seen it once in the skiagraph of a boy of fifteen and it is figured twice in Grashey's atlas.

The *secondary trapezoid*, found on the dorsum, represents the tip of the radial side of the base of the second metacarpal resting against the trapezium and the trapezoid. It has been seen five times as a distinct bone with articular surfaces. It is therefore not the result of a fracture. Pfitzner has seen it marked off by a line from the metacarpal.

The *parastyloid*, once found free, is the ulnar projection on the dorsum of the base of the second metacarpal.

The *styloid* is the most frequent of these extra bones in the hand and illustrates most perfectly Pfitzner's views. It is found in some 69 per cent. of young embryos as a separate centre which habitually fuses with the third metacarpal, forming its styloid process slanting obliquely between the trapezoid and the os magnum. It may be distinct with articular surfaces, or fused with either of these bones. When it fuses with the os magnum the distal line on the dorsum of the latter is practically transverse. In the ordinary X-ray taken with the hand prone the focus is such that we get the view of the palmar aspect. The second metacarpal is seen astride of the trapezoid, and the styloid is usually impossible to define. I have seen however in X-rays the transverse distal border of the os magnum which is characteristic of a fused styloid and I have two or

three times seen a separate styloid though not very distinctly. In bones I have seen many forms. Pfitzner made one curious observation concerning the relative arrangement of the bones in each hand. The styloid may be fused with the third metacarpal in one hand and with either the os magnum or the trapezoid in the other; but it never is fused with the trapezoid in one hand and with the os magnum in the other. When it is fused with the trapezoid it gives the latter a curious transverse elongation. It may be, as above stated, in relation with the bones in question by a true joint or a true bony connection, or in place of the latter the connection may be by fibro-cartilage. In 1450 hands Pfitzner found it connected one way or the other with the metacarpal in 1397, with the os magnum in 54, and with the trapezoid in 16. This series of course includes cases of its being connected with more than one of these bones. As I have determined to avoid purely scientific discussion in this work, I shall merely make the bare statement that I have seen the styloid more than once in two places in the same hand; as, for instance, represented by a swelling on both the metacarpal and the os magnum. I mention this only because the fact is worth noting from its practical importance.

The *metastyloid* is an uncommon, and practically unimportant ossicle in the dorsum between the point of the styloid process of the third metacarpal and the os magnum and trapezoid. It may be free or fused with either of the others. Pfitzner speaks of its maximum size being 5.5 mm., but usually it is quite insignificant. I have a specimen of about 5 mm. diameter coalesced with the trapezoid but plainly marked off.

The *Vesalianum* or *bone of Vesalius* is the tip of the ulnar side of the base of the fifth metacarpal. It is situated between the metacarpal and the unciform, or it may be prolonged from the former to lie on the outer side of the latter. It is named after Vesalius because he described it as a constant element, considering it a sesamoid. It has been seen several times, if not free, at least plainly marked off on the base of the metacarpal. I have seen an X-ray in which apparently it was wanting. In fact it may have remained cartilaginous. The size of the tuberosity of the fifth metacarpal varies widely quite independently of the bone of Vesalius, which represents only a part of it.

The *phalanges* also may be longer or shorter than normal. Lengthening when there is no question of compensation is not common nor very noticeable. I incline without categorical proof to think it more frequent in negroes. An extra phalanx is found very rarely in the thumb. In the case of a family recorded by Rieder,[1] the middle phalanx ranged from a well-formed one to a small rudiment larger on one side than on the other, so as not to separate com-

[1] Deutsches Archiv für klin. Med., Bd. 66.

pletely the proximal and distal phalanges. The extra phalanx seems to tend to be absorbed into the terminal one. The oblique line of separation might be mistaken for a fracture in an X-ray plate. In no case did the extra phalanx have an epiphysis in those of an age at which it is to be expected. Shortening and suppression of phalanges occurs apparently most often in the middle row, the one in which ossification appears last. This condition is associated with webbed fingers. The phalanges of the last row are sometimes small and ill-developed. Pfitzner calls the attention of anthropologists particularly to some cases in which the last phalanx of the thumb is about one third shorter than usual but beautifully formed.

Sesamoid bones of the hand. It has been already stated that these are more numerous in the fœtus than later. We assume that there is originally in the human hand a pair at each metacarpo-phalangeal joint, though all have not yet been observed. The following table is taken from Pfitzner. The first row shows the percentage found by Thilenius[1] in 30 hands of embryos of the fourth month, and the second row the percentage in 1440 hands from fourteen years up to eighty-nine as found by Pfitzner. In order to name each bone it is easier to call those of each finger the radial and the ulnar sesamoid rather than the outer and inner. The Roman numerals indicate the finger, including the thumb as I.

	I.		II.		III.		IV.		V.	
	R.	U.	R.	U.	R.	U.	R.	U.	R.	U.
Embryos..	(100	100)	(46	23)	(30	15)	(23	30)	(8	84)
Adults ...	(99.9	100)	(48.7	0.1)	(1.4	0)	(0	0.1)	(2.1	82.5)

It is easy to infer from this that the most common arrangement in the adult is that presenting two in the thumb, one on the radial side of the index and one on the ulnar side of the little finger. A. Stieda[2] has since found with the X-ray a radial sesamoid in the fourth finger in two hands.

Subdivision of the radial sesamoid of the thumb. Pfitzner found this three times, once in both hands of the same body, which pretty well excludes fracture. He once also in an individual of seventeen years found the two pieces united by a strip of cartilage. They lie side by side, but there is a tendency for the radial one to be placed somewhat more proximally than its fellow.

A sesamoid bone between the first and second phalanges is found frequently in the thumb opposite the middle of the joint. Pfitzner believed it to consist of two lateral elements fused. He once found it in two pieces, but the specimen was not above suspicion. Discarding that, however, he found it three times, twice on each hand of one body, with a furrow dividing two equal lateral halves.

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[1] Morph. Arbeiten, Bd. v, S. 319.

[2] Beiträge zur klin. Chirurg., 1904.

In time it will doubtless be found in two pieces. Once Pfitzner found a corresponding bone in the index.

Sesamoid bones on the dorsum, at the metacarpo-phalangeal joints, are observed in certain orders of mammals, but in man have been seen only twice, both in the thumb, once by Pfitzner and once by Kulmus.[1] The former describes his case as a globular ossicle of 1.5 mm. diameter in the posterior wall of the capsule.

FUSION OF BONES OF THE HAND.

Fusion of the scaphoid and semilunar after the fashion of the carnivora has apparently not been observed in man. I have never seen it without still more extensive fusions which pass the limit of ordinary variation.

Fusion of the semilunar and cuneiform. According to my own observations the fusion of these elements is always bony. There are, however, cases in which, though a true joint is wanting between the pieces, they may be separated by maceration. The union almost always occurs at the proximal surface of the bones at the place where they are normally connected by an interosseous ligament. Almost always there is a furrow on the distal surface marking the original line of separation. Exceptionally the union is perfect throughout. Pfitzner once saw it at the distal dorsal end. The hands which I have observed show absolutely nothing pathological. This fusion should be shown by the X-ray, but I am not aware that it has ever been so observed. Pfitzner has pointed out the relative frequency of this condition in the blacks. He had collected the accounts of fifteen cases, six being his own, of which five were from negroes. Since then Prof. G. Elliot Smith[2] observed fusion in both hands of a Soudanese negro. Still later Dr. Derry[3] announced that Smith had since observed it three times in six individuals of the same race. It was present in both hands of a woman and in one of a man, whose other hand was not examined. I have met with it six times: once in both hands of a negro, twice in one hand of a negro or mulatto, one male the other female, and twice in hands of unknown origin. Thus of twenty-six observed cases at least fourteen are from blacks.[4]

Fusion of the cuneiform and pisiform. There is but one observation[5] of fusion of these bones when they were the only ones affected. It occurred on

[1] Tabulæ Anatomicæ, Amsterdam, 1732.

[2] On a Case of Numerical Reduction of the Carpus, Anat. Anzeiger, Bd. xxiii, 1903.

[3] Journ. of Anat. and Phys., vol. xli, 1906.

[4] Since the above was written a case of very complete fusion of these bones in the right hand of a white man is reported by A. A. M'Connell in the July, 1907, number of the Journ. of Anat. and Phys., vol. xli. The left hand was normal.

[5] Wedding, Dissertation, Berlin, 1832.

both sides. It is worth mentioning that in cases of general fusion (presumably pathological) of the carpus these two bones are the last to unite.

Fusion of the trapezoid and the scaphoid. Complete fusion has once been noted by Turner.[1]

Fusion of the trapezoid and os magnum. These have been seen joined at the dorsum both by bone and by fibro-cartilage, by both Pfitzner and Anderson.[2]

Fusion of os magnum and unciform. This has been seen only by Pfitzner, once in both hands and once in an odd hand. The union appears to have been complete except for a furrow on the distal side.

Fusion of the second metacarpal with the trapezoid. Pfitzner has seen these bones joined by fibro-cartilage in three cases. I have seen bony union at least once. Though there were no clear signs of disease in other places, the specimen has a pathological look.

Fusion of the third metacarpal with the os magnum and trapezoid. Fusion with the os magnum has been observed so far, I believe, only when the union was cartilaginous. It may occur by means of the styloid, but not necessarily. Fusion with the trapezoid may occur through the styloid or otherwise and may be either bony or cartilaginous. I have one specimen in which the dorsal parts of the bones had evidently been joined by cartilage. Solger[3] found the cartilage of the os magnum and third metacarpal continuous in an infant.

General fusion of the bones of the wrist, so far as I have observed, is either teratological, as in cases of extra fingers, or pathological. Still there is room for doubt. I have a hand (of uncertain origin) in which the scaphoid is fused with the semilunar, the second metacarpal with the trapezoid, and the third metacarpal with the os magnum, chiefly through the styloid. It is pathological.

Fusion of the fourth and fifth metacarpals. I have seen this once in a normal left hand, the bones being united for about one-third of their length at the proximal end. I give a figure of a similar condition observed in both hands of a lad of eighteen, only the fusion was somewhat greater and the distal end of the fifth metacarpal undeveloped so that the bone was not more than two-thirds of its proper length. With this in my mind I reëxamined the bony specimen and convinced myself that the fifth metatarsal is a little shorter than usual.

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[1] Some Variations in the Bones of the Human Carpus, Journ. of Anat. and Phys., vol. xvii, 1883.

[2] Division of the Scaphoid Bone of the Carpus, with Notes on other Varieties of the Carpal Bones, Ditto, 1883.

[3] Centralblatt der allg. Path. und Path. Anat., Bd. i, 1890.

THE FOOT.

No time is to be spent in attempting an arrangement of the tarsal bones into transverse and longitudinal rows, nor in discussing their homologies with those of the carpus. There are in the foot as in the hand a number of occasional bones to be accounted for by the persistence of embryonic elements which normally lose their individuality by early fusion or by disappearance. It is to be noted that two elements of the theoretical tarsus are described in human anatomy as sesamoid bones, namely those of the tendons of the *tibialis posticus* and *peroneus longus*. In the following list I have followed Pfitzner much less closely than in the hand, omitting several elements which he names, but concerning some of which he has well-founded doubts as to whether they are not pathological, and others which while not pathological have never been seen separate.

1. *Trigonum.* This is the external posterior process of the astragalus (or a part of it). 2. The *astragalus.* 3. The *os calcis.* 4. *Os sustentaculi*, the posterior end of the sustentaculum. 5. The *peroneal spine.* The process on the outer side of the os calcis separating the tendons of the peroneus longus and brevis. The Germans name it *processus trochlearis calcanei.* (It is not certain that this is a distinct element.) 6. *Calcaneum secundarium* (secondary os calcis), the anterior superior angle of the os calcis situated at the point where that bone and the astragalus meet (approximately) the scaphoid and cuboid. 7. *Tibiale externum*, commonly known as the sesamoid bone in the tendon of the tibialis posticus. 8. The *scaphoid.* 9. *Cuboides secundarium* (secondary cuboid), commonly fused with either the cuboid or the scaphoid in the sole of the foot where these bones nearly meet. 10 and 11. *Internal cuneiform*, subdivided into (1) a dorsal and (2) a plantar part. 12. *Intercuneiform.* A bone on the dorsum between the proximal ends of the internal and middle cuneiforms resting against the scaphoid. 13. *Middle cuneiform.* 14. *External cuneiform.* 15. *Cuboid.* 16. *Peroneum.* This is very rarely found in bone or true cartilage; it is represented by the thickening in the tendon of the peroneus longus and is called a sesamoid bone. 17. *Intermetatarseum.* A bone situated at the junction of the internal cuneiform and the first and second metatarsals. 18. *Vesalianum*, the tip of the tuberosity of the fifth metatarsal.

We shall now consider the several bones together with the occasional elements which are most intimately associated with them, at the same time calling attention to the other variations of the regular bones. Then we shall deal with the fusions of the bones and their uncommon relations.

VARIATIONS AND ADDITIONAL BONES.

The *astragalus* and *trigonum*. The hind part of the astragalus is drawn out backwards into a projection, grooved by the tendon of the flexor hallucis muscle, which runs obliquely downwards from without inward. The outer border of this groove is made by the *posterior external tubercle*. The inner border may be very ill-defined or may be marked by the *posterior internal tubercle*. The *external tubercle* on the outer border of the groove has not the slightest mechanical function unless perhaps that it prevents the tendon from falling outwards during the total relaxation of the muscle. Certainly when the muscle is contracting, the tubercle is of no value. On the outer side of this tubercle is the *trigonum*, which in some 7 or 8 per cent. is a distinct bone. Its lower surface continues the articulation of the astragalus with the os calcis. As the question of fracture is brought up in connection with this occasional bone, it is proper to show what are its claims to be considered a part of the skeleton.[1] v. Bardeleben found it a distinct piece of cartilage in the second month of embryonic life, situated between the bones of the leg. It is therefore homologous with the *triangulare*. I have found it distinct in cartilage at birth. It is hardly to be found in animals except in the marsupials, but is constant in those of that order which have five toes. As to its size and development it is very variable. It has been seen hooking over the groove. It may represent practically the whole of the external posterior process. Though Pfitzner has never seen it make the actual border of the groove, I incline to think it may do so.[2] On the other hand there may be a very long process with the trigonum situated at its end. An instance is shown in fig. 35.

Pfitzner insists very strongly that it is not the same thing as the tubercle. Very rarely it has been found in two pieces. I have such a specimen which offers no suggestion of violence. When it is free it is generally joined to the astragalus by a little fibro-cartilaginous tissue, the bony surfaces being in close apposition. Exceptionally there may be a true joint. Sometimes the union may be by cartilage. When it is truly fused so that there is but one bone the outline of the trigonum may be perfectly clear, or very hard to make out. The trigonum tends to be in the main symmetrical, but may be distinct on one side and fused on the other. The statistics of the frequency of the trigonum are very unsatisfactory; first because there is a discrepancy in the use of terms. Pfitzner speaks of separate (selbständige) trigona. Sewell speaks of "evidence of sepa-

[1] Weber, Das Intermedium Tarsi. Sitzungsbericht. Jenaische Gesellschaft für Medicin und Naturwissen, 1883.

[2] Consult Sewell, A Study of the Astragalus, *Journ. of Anat. and Phys.*, vol. xxxviii, p. 426. This series of papers on the astragalus is continued in the two following volumes.

ration," which is an indefinite term. Again, not only fused, though clearly marked off, trigona may be easily overlooked, but a free one may be so closely joined by synchondrosis as not to be recognized without great care. Pfitzner put the frequency at from 7 to 8 per cent., basing his judgment on specimens which he himself had thoroughly examined and rejecting series which most other men would have accepted. It is therefore very common. Bearing in mind what has been said of the embryology and comparative anatomy, no one now would seriously maintain that it is the result of a fracture. It cannot indeed be denied that a trigonum loosely attached might be broken off, but it is so sheltered that it is hard to see how this accident should occur. It is supposable that it might be pulled off, especially if originally distinct, by the strain of the posterior bundle of the external lateral ligament of the ankle.[1] It is often very well shown by the X-ray, but probably when the connection is a close one it may be difficult to recognize.

The *posterior internal tubercle*, though usually small or even absent, is exceptionally very strongly developed. It cannot be accounted for by any element which is usually wanting. It therefore is simply a case of hypertrophy of a part of the skeleton for which there is no satisfactory explanation. It might perhaps pass as one of Hyrtl's trochlear or pulley-like processes, as the tendon of the flexor hallucis plays on it. The astragalus shows occasionally an upward projection from the dorsum just behind the head. Hyrtl described it as one of his trochlear processes. It has a distinctly pathological appearance suggesting an exostosis. There is, however, a certain family likeness between specimens. Be the cause of the process what it may, it is worth knowing that it occurs.

The astragalus (and the same may be said of the os calcis) is a very variable bone in respect to its general conformation. It may be long and narrow or short and broad; the neck may diverge much or little from the axis of the body, the shape and inclination of the head are very uncertain. It can hardly be doubted that these variations must have an important influence on the shape of the foot and on its movements. But the genius who should work this out has not yet appeared. Parker and Shattock[2] reckoned the angle of the neck, that is its lateral divergence, as the angle formed by a line parallel with the inner border of the superior articular surface and one parallel with the outer border of the neck. The inclination to the side as shown by this angle is much greater in the anthropoids than in man. The human fœtus in this respect resembles the apes. These observers found the average angle in twenty adults 10.65, the maximum being 26 and the minimum too little to be measured. In the fœtus

[1] Vollbrecht. Fortschr. a. d. Gebiet. d. Röntgenstrahlen, 1900.

[2] Pathology and Etiology of Club-Foot, Trans. Path. Soc. of London, vol. xxxv, 1884.

from the fourth month to term the average angle of eleven cases was 38, the maximum 42 and the minimum 35. The series is of course too small to show anything more than the main fact.

The *os calcis*, the *os sustentaculi*, the *peroneal spine*, and the *secondary os calcis*. The first of these exceptional bones, the *os sustentaculi*, forming the hind end of the sustentaculum, is very uncommon. Pfitzner has seen it twice as a distinct bone, connected by fibro-cartilage, or fibrous tissue, and has several times been able to recognize its presence although it was fused. I have never seen it separate. It is of no practical importance (except as concerned in fusion of the astragalus and os calcis, of which later), and would be hard to show with the X-ray.

The *peroneal spine* (*processus trochlearis* of German anatomists) is generally described as a small ridge on the outer side of the os calcis separating the tendons of the *peroneus longus* and *brevis*. In point of fact it is found even tolerably developed so as to be distinctly discernible in only about 40 per cent. of feet according to Pfitzner, Gruber, and Stieda. The first of these thought he saw evidence once or twice of its having once been a separate bone, but there is not much to be said in support of this view. It is more probably to be considered (like the internal posterior process of the astragalus) one of those processes often absent and occasionally greatly developed. It is shown in several of these illustrations. The museum has one specimen in which it is much larger than usual; but it must be owned that it has the appearance of being at least in part formed by a pathological ossification of the fibrous tissue separating the tendons. Such a structure might be mistaken during life for an exostosis. Another much more important specimen from a negro, who presented the same appearance on both sides, shows it as a truly immense projection from the side of the os calcis, so as to be less a process than a large part of the bone. It recalls very strongly the appearance presented by the chimpanzee alone among anthropoid apes. Pfitzner figures a similar but perhaps less striking case which was present in both feet of a German woman of twenty-two. It would be very confusing clinically.

The *secondary os calcis* is very puzzling, inasmuch as the term seems to be applied to two distinct structures. The most typical one forms the very front of the sustentaculum and is usually a small bone with a convex posterior border fitting accurately into a corresponding concavity in the front of the sustentaculum. The other non-typical form (which I cannot feel sure is really the same thing) is a non-articular, rough, ill-defined projection from the front and top of the os calcis, pointing towards, if it does not reach, the space between the scaphoid, cuboid, and the head of the astragalus. It is apparently by an overdevelopment of this process that the os calcis and scaphoid are occasionally

brought into contact. Once I have seen, in a very pathological foot, what looked like a bone in this place which earlier had been distinct but had been absorbed into the os calcis.

The variations of the os calcis are many and striking.[1] Probably one of the most significant is the development and position of the external tubercle at the back. Always much smaller than the internal one, it may be just about in the same transverse plane with it or decidedly in front of it. Sometimes it is not to be made out; at other times it is very prominent. All this must have an effect on the way in which the weight of the body is transmitted. The development of this external tubercle must modify very sensibly the outline of the posterior aspect of the foot. This bone also varies in its curves in a way not easy to analyze.

Scaphoid, tibiale externum, and *secondary cuboid.* The scaphoid varies a good deal in its shape, but the causes are almost entirely due to the two bones just mentioned. The tuberosity of the scaphoid is not necessarily the same thing as the *tibiale externum*, but may vary within certain limits. When the projection is very large, particularly when its end is more or less marked off and especially if it is turned backwards, we have to do with a *tibiale* more or less perfectly fused with the tuberosity. The *tibiale externum* is commonly known as the *sesamoid in the tendon of the tibialis posticus*, but it is a true part of the skeleton, being found in many mammals and being cartilaginous in the second month of the embryo. I have seen it as a separate cartilage at birth. Fig. 62 shows it in a child of two years. In about 10 per cent. this is a separate bone, generally closely connected with the tuberosity of the scaphoid by fibro-cartilage or fibrous tissue. It may play on it with a true joint; but more often the articular cartilage, even when present, shows signs of degeneration and the two apposed surfaces tend to interlock. It is more or less involved in the tendon of the posterior tibial. It sometimes is quite free, having no close connection with the scaphoid, but, as Pfitzner has shown, it is never *inclosed* in the tendon. Its relation to the tuberosity of the scaphoid is uncertain, whether it persists as a distinct element or is consolidated with the latter. It may be placed directly internal to the tuberosity, but more often it is somewhat behind it, and sometimes so much so that it seems to form a link between the tuberosity of the scaphoid and the front of the sustentaculum beneath and internal to the head of the astragalus. When fused it may stand straight out as a projection from the scaphoid or it may bend backwards as a well-defined hook, or it may be so completely fused that its presence is inferred only by the size of the prominence. If it pleases any one to say that it is simply a very large tuberosity there is no

[1] Consult Laidlaw, Journ. of Anat. and Phys., vols. xxxviii and xxxix.

way of convincing him, nor does it practically matter. Pfitzner has once seen it subdivided, and in two or three other cases an imperfect division was indicated by furrows. The tendency of an independent *tibiale externum* is to be symmetrical. Thus Pfitzner found it 26 times on both sides and only 17 times on one side. He found it nearly twice as often in women as in men. As to size, the largest seen by Pfitzner had a chief diameter of 19 mm. He found but five under 5 mm., showing that very minute forms are rare. It is evident that this may be mistaken for a fracture. The hook-form is shown by the X-ray very clearly.

The *secondary cuboid.* Pfitzner identified this occasional bone without ever having seen it separate. Since then Schwalbe has once seen it distinct and I have a specimen in which at an earlier period it almost certainly was so. In spite of its name it is more frequently fused with the scaphoid than with the cuboid and it is considered in this paragraph only as connected with the former. Situated at the lower outer edge of the scaphoid, it gives that bone, when fused with it, a more or less quadrangular shape. It sometimes is so bent as to be continued proximally into the sole of the foot. I have once seen an X-ray in which it was tolerably clearly indicated as a circular disc in the sole. In other cases, and probably in most, it is not much bent under the sole, but attached to the lower part of the scaphoid, giving it a characteristic four-sided outline. Sometimes it touches the cuboid by a considerable border, thus bringing the scaphoid and cuboid into contact. They may be connected by fibro-cartilage. The dorsal border of the front of the scaphoid may be pretty nearly a continuous line, or it may present one or two points at the interspaces between the cuneiform bones. The inner one of these probably represents the *inter-cuneiform* bone (described later) which I observed between the proximal ends of the internal and middle cuneiforms. I strongly suspect that in course of time a similar bone will be found between the middle and outer cuneiforms represented now occasionally by the outer point.

Hyrtl described an elevation on the dorsum of the scaphoid very like the one above the head of the astragalus which he also named a trochlear process. I have seen a case very like his. I believe it to be pathological; but, as said of the preceding instance, it is worth knowing that it may be found just in this place and that in all probability is not the result of a lesion.

Subdivided internal cuneiform. This very striking variation is extremely rare. I have never seen it, though I have searched for it carefully for years. In a typical case the bone is divided into a dorsal and a plantar half. I have found it in an X-ray of a child. (Figs. 61 and 62.) A line on the anterior surface hinting at a division is very common.

The *intercuneiform.* This is a small wedge-shaped bone with a dorsal triangular surface situated on the dorsum of the foot close in front of the sca-

phoid separating the proximal parts of the internal and middle cuneiform bones but apparently cut off from the latter rather than from the former. I am the only one who ever observed it, and, curiously enough, have seen it twice.[1] I have a rather vague recollection of having seen it also many years ago before I knew enough to appreciate it. The interpretation of skiagraphs of this region of the foot strikes me as difficult. I think I have seen this bone thus shown at least once (whether quite distinct or partly fused with the middle cuneiform I cannot say), but I do not dare to feel sure of the observation.

The *middle cuneiform*. Of this bone there is nothing to say.

The *external cuneiform*. There would be nothing to say of this bone were it not that the cat tribe especially, as well as some others of the carnivora, have a hook-like process, *os unci*, on the distal end of the plantar surface, of which Pfitzner saw one instance in man. It may have some relation to the fusing of this cuneiform with the third metatarsal which is considered later.

The *cuboid*. Of this bone also there would be nothing to say were it not for the *secondary cuboid*, an occasional bone, the relations of which with the scaphoid have been already discussed. It may be found fused with the cuboid, presenting a well-marked process under the head of the astragalus, with which it may articulate.

The *peroneum*, commonly known as the *sesamoid in the tendon of the peroneus longus*, occurs in less than 10 per cent. It may be a large bone nearly filling the depression in the side of the cuboid on which it plays, a bursa intervening, or it may be more closely in relation with the calcaneum. It may be subdivided. The largest I have seen measured before maceration nearly 2 cm. and was more than half as broad, but ossification had invaded the tendon.

The *intermetatarseum* is a very interesting bone, found in some 10 per cent. between the internal cuneiform and the first and second metatarsals. It has been called with considerable plausibility a part of a ray which has dropped out of the plan, the bone representing the base of a metatarsal. Some representatives of a shaft have lately been described.[2] It might perhaps be as well accounted for as a futile attempt at polydactylism. Gruber once found the bone represented in cartilage at birth. The bone may be free, or fused with any one of the three neighbours. In one case it joined each by an articular surface; but it usually is fused with one and in contact with one or both of the others, probably more often without a true joint. It tends to present a point at the distal end. What may be called its base rests usually on the internal cuneiform. The most common form in my experience is to find it fused with the

[1] Anat. Anzeiger, Bd. xx, 1902.

[2] Lunghetti, Anat. Anzeiger, Bd. xxviii, 1906, S. 479.

internal cuneiform so that it presents an elongation of the outer distal angle of that bone on the dorsum, which may be marked off with various degrees of clearness. When fused with the second metatarsal it projects forwards and inwards, having much the look of an exostosis. I have seen but two cases of synostosis with the first metatarsal. All these forms are in the Warren Museum. Here is a bone which may be 1 cm. or more in length placed in an interspace so that one would expect it to be a prominent feature in skiagraphs, and one which might easily give rise to a wrong diagnosis of fracture or of exostosis. In point of fact this region shows very badly with the X-ray, apparently owing to a confusion of the lines of the two surfaces. Be that as it may, I do not remember to have seen on plates a single *intermetatarseum* which struck me as satisfactory.

The metatarsals. The first metatarsal shows considerable variation in the plantar end of the base which may be prolonged and which Pfitzner suspected to contain an undescribed element. It is doubtful whether this would have any practical importance. It is not uncommon to find a bursa and other more or less distinct signs of a joint between the first and second metatarsals near their bases. An articular facet of hyaline cartilage is found on the first in about 25 per cent., according to Gruber.[1] I cannot remember ever having seen a corresponding true facet on the second; but Gruber states that of the feet having this joint one quarter present on the second metatarsal a facet of hyaline cartilage, one half a coating of fibro-cartilage, and the other quarter a thickening of the periosteum.

The Vesalianum, corresponding to the bone of the same name in the hand, is the proximal and external part of the tuberosity of the fifth metatarsal. It is excessively rare. I have never seen it in the macerated foot of an adult. Spronck[2] has seen it at birth, and I think I have probably made the same observation.[3] I have once seen it in the skiagraph of a girl of twelve. The entire base of the fifth metatarsal varies very much in size. The *Vesalianum* is usually more or less marked off by a groove on the plantar surface. Gruber[4] has seen a proximal epiphysis, not to be confounded with the Vesalianum, distinct in an adult.

The phalanges. Apart from minor variations in length, the most important

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[1] Memoirs Acad. St. Petersburg, xvii, 1871.

[2] Anat. Anzeiger, Bd. ii, 1887.

[3] The bones had been separated by Thilo's method or by a modification of it; but as I made some slight use of the scalpel I had an uneasy feeling that I might have made a cut, though I am not aware of having done so. I prefer to speak of the observation as doubtful.

[4] Archiv für Anat. und Phys., 1875, S. 48.

feature is the occasional atrophy of the bones of the middle and terminal rows. That of the middle phalanx of the little toe is the most marked and common. It shall be considered in the next section treating of fusions. The middle phalanx may be wanting in all the toes. The terminal phalanx shows a considerable range of forms. It may be small and degenerate especially in case of fusion with the middle phalanx.

The sesamoid bones which may be found in the metatarso-phalangeal joints and in the joint proximal to the last phalanx are as follows: The two under the head of the first metatarsal are constant; then there is an interphalangeal one of the great toe, opposite the middle of the plantar aspect of the joint, in 50.6 per cent., a tibial one of the second toe at the metacarpo-phalangeal joint in 1.8 per cent., and two in the same joint of the little toe, the tibial in 5.5 per cent. and the fibular in 6.2 per cent. There is, moreover, a distal interphalangeal one opposite the middle of the joint of the second toe in 8 per cent. As just mentioned, the first two are constant. They are, moreover, the only ones present in 40.7 per cent. The most common combination is when there is also the distal sesamoid of the great toe. This occurs in 48 per cent. No other combination is worthy of notice. All this is according to Pfitzner.

Subdivision of the internal sesamoid of the great toe is not so very uncommon, the division being by a cross line into a larger proximal and a smaller distal part. I have seen this several times both in the bones and in X-rays, and have seen once the external divided in the same manner with the suspicion of a longitudinal division of the larger piece. Stieda[1] found two sesamoid bones of the plantar aspect of the interphalangeal joint of the great toe and at the same time a subdivided sesamoid at the metacarpo-phalangeal joint. The man had suffered from a previous injury to the ball of the foot. He saw twice a tibial sesamoid of the fourth toe with the X-ray.

FUSION OF BONES AND VARIATIONS OF RELATIONS.

Fusion of astragalus and os calcis. The abnormal condition occurs at the posterior end of the sustentaculum and may be attributed to the os sustentaculi fusing with both bones. The bones may be firmly co-ossified or they may be united by gristle, the apposed surfaces showing the characteristic irregular finish. Either of these conditions is decidedly uncommon.

Fusion of astragalus and scaphoid. There are a very few recorded cases, some of which seem certainly not to be pathological. I have never seen it.

[1] Beiträge zur klin. Chirurgie, 1904.

The relations of the scaphoid to the cuboid and to the os calcis. Normally the *scaphoid* and *cuboid* are connected by ligament, but very frequently there is a true joint. Gruber[1] found one present in 45.5 per cent. of 200 feet. Pfitzner found an evident joint in 50.4 per cent. of 437 feet. Among notes taken by me several years ago I find records of the presence or absence of this joint in 200 feet with the result that it was present in about 60 per cent. A difficulty in such statistics is that occasionally the joint is very small or ill-marked, suggesting that the bones have merely a bursa between them instead of a true joint. It is to be noted that Pfitzner excluded some which he called "minimals." It is distinctly more common in women than in men, but Pfitzner's figures on this point are not large enough for a true average. Fusion of these bones or connection by cartilage is very rare. I have seen bony connection once and cartilaginous once or twice. Pfitzner has seen the latter three times, twice in one body. The os calcis may project forward so as to reach the end of the scaphoid, thereby crossing the line of Chopart's amputation, and may be connected with it by a true joint, by synchondrosis, or by synostosis. Cartilaginous union has been seen at birth. The os calcis may reach forward only far enough to just touch the scaphoid, in which case the latter lies against the cuboid as well; or it may go so far forward as to exclude the cuboid from any relation with the scaphoid. The question has arisen whether synchondrosis of these bones has any important effect on the shape of the foot. Holl believed it to be a cause of flat foot. My experience tallies exactly with Pfitzner's, who disagrees with this theory. We both have seen beautifully shaped feet with high arches when this arrangement exists, but we also have seen some cases of broken-down foot. Probably it has no effect one way or the other.

Fusion of the middle and outer cuneiform bones. One single instance of this was observed by Pfitzner on an odd foot, otherwise normal and healthy. The union was between the plantar halves of the bones. The same author had seen this fusion in the dog and the cat.

Fusion of the external cuneiform and the third metatarsal. This by no means very rare variation has been reported only by Pfitzner. I have, however, met with three or four cases myself. It occurs, like the rest, at the plantar surface and may be by cartilage or bone. It is often found on both sides. Pfitzner has seen it fourteen or fifteen times. He reports a case of a boy of seventeen with it on both sides, chiefly cartilaginous but with beginning synostosis. I have seen a foot of a girl of nineteen, beautifully formed and perfectly normal, in which the union is bony but present only at the plantar end of the joint. Pfitzner is inclined to ascribe it to an exceptional element, the *os unci*, on the under side of the cuneiform.

[1] Arch. für Anat. Phys. und wissen. Med., 1871.

The relations of the external cuneiform to the cuboid and to the base of the fourth metatarsal. It is generally taught that the line of Lisfranc's amputation, external to the irregularity caused by the shortness of the middle cuneiform, describes a continuous curve; but, as apparently Lisfranc himself knew, there is very frequently an irregularity caused by the projection of the external cuneiform beyond the cuboid so as to be in relation with the inner surface of the base of the fourth metatarsal, to which it may be connected by a joint.

The relations are best shown by this table, which I have compiled from the researches of Pfitzner on 438 feet.

The projection of the cuneiform beyond the cuboid is							2mm.	or	less	in	45.7	per cent.
"	"	"	"	"	"	"	3	"	"		3.2	" "
"	"	"	"	"	"	"	4	"	"		10.3	" "
"	"	"	"	"	"	"	5	"	"		18.9	" "
"	"	"	"	"	"	"	6	"	"		11.9	" "
"	"	"	"	"	"	"	7	"	"		7.8	" "
"	"	"	"	"	"	"	8	"	"		2.1	" "
"	"	"	"	"	"	"	9	"	"		.1	" "

Fusion of the cuboid with the fourth and fifth metatarsals. There is no record of this ever having been seen *post mortem.* I have seen it with the X-ray in both feet of a man of about thirty suffering from pain at that joint following gonorrhœa. It was presumably pathological.

Fusion of the middle and terminal phalanges of the fifth toe has been observed by Pfitzner in 37 per cent. This fusion, which certainly is not pathological, and which occurs in embryos and children, is due, as he has shown, to the absorption of the middle phalanx into the terminal one. Its frequency is easily verified by the X-ray. It is to be noted that the terminal phalanges, besides the centre for the shaft, and that for the proximal epiphysis, have also a cap-like ossification which soon joins the free end of the terminal phalanx. In cases of fusion of the phalanges it seems that the proximal epiphysis of the middle phalanx is wanting (in fact I think it generally is wanting in the little toe) as is also the body of the terminal phalanx. The proximal epiphysis of the latter is very large and is joined by the cap, the centre of the last phalanx not appearing. This compound piece then joins the centre for the rudimentary middle phalanx. The line representing the distal end of the middle phalanx may be seen on the surface of the bone, but both sections and the X-ray show a perfect continuity of structure.

Coalescence of the middle and terminal phalanges occurs in other toes than the fifth, but more and more rarely towards the inner side of the foot. Moreover the progress inwards is perfectly regular. Thus according to Pfitzner the fourth toe never shows it when it is not present in the fifth, nor the third if it be not

present in the fourth and fifth, nor the second if it be not present in the three beyond it.

I have often seen in X-rays of children's feet an appearance which I am rather at a loss to explain, and of which I find no account. It seems as if the little toe had four phalanges. I can only infer that the proximal epiphysis of the second phalanx is so large as to be mistaken for a phalanx. I have once seen a strong suggestion of the same condition in the skiagraph of an adult foot.

PLATES SHOWING THE VARIATIONS OF THE BONES OF THE HANDS AND FEET

PLATE I.

FIG. 1. This man has a supernumerary bone, presumably the *triangulare*. The X-ray shows some pieces of stone which had been driven into his hand by an explosion. The suggestion that the piece might be a separated styloid process of the ulna is not pertinent, as the styloid process is intact. It is not impossible, however, that it should have been separated from the tip of the styloid process. Pfitzner figures a swelling on the end of the styloid which he considers a *triangulare*.

FIG. 2. A *divided scaphoid* (without fracture) on the right hand of 440, white, male, æt. 61. The semilunar has a minute *epilunatum* fused with it. There is a separate bone, presumably an *epipyramis* with its long diameter (1 cm.) placed transversely on the dorsal aspect of the cuneiform, overhanging the unciform. The opposed surfaces, between it and the cuneiform, are rough. It may be a *post-mortem* fracture. Neither of these is shown in the photograph. The left hand shows a beautiful *epilunatum* free (vide fig. 14). These peculiarities are insisted on as indicating a tendency to the multiplication of free elements in this body. The two pieces of the scaphoid were perfectly in place. It was possible by using considerable force, while holding the detached bone in both hands, to make the two parts play very slightly on each other. The line of separation had the characteristic position (vide p. 4). A section showed the pieces united by cartilage. Dr. E. H. Nichols was kind enough to examine the specimen microscopically and reported that there was no fracture. Fig. 8 shows the appearance of the isolated bone and fig. 9 shows an X-ray of this bone.

FIG. 3. (413, old number), white, male, æt. 74. This is a *divided scaphoid*. The division may be the result of an error in development or it may be the result of a fracture of a normal bone. Assuming that the bone developed in two pieces we may say that they have not kept their primitive condition, like those of the preceding specimen, but have played one on the other, to the destruction of the joint, or of the intervening cartilage. It is very possible that there was both an original division of the bone and also a subsequent lesion. An additional bone on the dorsum (just above the arrow) is to be considered a *centrale*.

PLATE I.

FIG. 2.

FIG. 3.

FIG. 1.

PLATE II.

FIG. 4. X-ray of a fracture of the radius and a *divided scaphoid*. I have no history of this case, beyond that it is that of an adult male examined at the hospital and diagnosed as fracture of the radius and of the scaphoid. The fracture of the former bone is beyond question; but if any one will contrast the well defined border of the cleft between the two parts of the scaphoid with the interlocked edges of the radius and will further compare this line through the scaphoid with that separating several of the other bones of the wrist he will see that there is no evidence of a fracture. The diagnosis was probably made on the assumption that if the scaphoid be found in two pieces it must be in consequence of an injury.

FIG. 5. X-ray of a scaphoid in two pieces. This is either a fracture or an instance of a divided scaphoid, the pieces of which have worked apart through a degenerative process. Very probably this condition was accelerated or initiated by a lesion occurring to a divided scaphoid, but the question cannot be decided.

FIG. 4.

FIG. 5.

PLATE II.

PLATE III.

FIG. 6. An X-ray of five left and two right scaphoids imbedded in sand, the hands being in the prone position. They should have been placed somewhat more longitudinally than has been done. They show a good deal of variation in structure, the two right ones especially having a large cavity near the middle.

FIG. 7. Four right and two left scaphoids seen from the distal and the ulnar side. The top one shows a fused *centrale* partly marked off. The same interpretation may be given to the point on each of the lower pair. The right one of the upper pair has a large cavity near the middle which must be a weak point. The lowest one has a line of nutrient foramina suggesting the place of union between the two original parts. This group shows very marked differences in shape which must be remembered in studying X-rays.

FIG. 8. Drawings of the scaphoid of the hand shown in fig. 2. The upper one shows the proximal and the lower the distal aspect.

FIG. 9. An X-ray of the same bone.

FIG. 10. Two different types of internal structure of scaphoid.

FIG. 6.

FIG. 7.

FIG. 8.

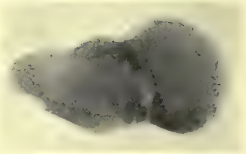

FIG. 9.

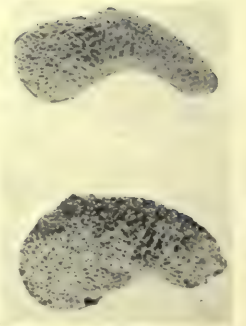

FIG. 10.

PLATE III.

PLATE IV.

FIG. 11. An X-ray of a young woman's hand showing a dark spot distal to the scaphoid, which might perhaps be interpreted as a *centrale* a little out of place. The more I have studied this photograph the more doubtful I have become of the correctness of this interpretation, but I have allowed it to stay as an instance of the difficulty of the study.

FIG. 12. X-ray of a male hand showing a cavity that should have been occupied by the *centrale*. In this case the bone may have completely disappeared during development or it may have remained cartilaginous. This is an uncommonly fine specimen of a tolerably common condition. It is to be noted that the hand is not at all turned to the ulnar side, under which circumstances more or less of a space generally appears at this point.

PLATE IV.

FIG. 12.

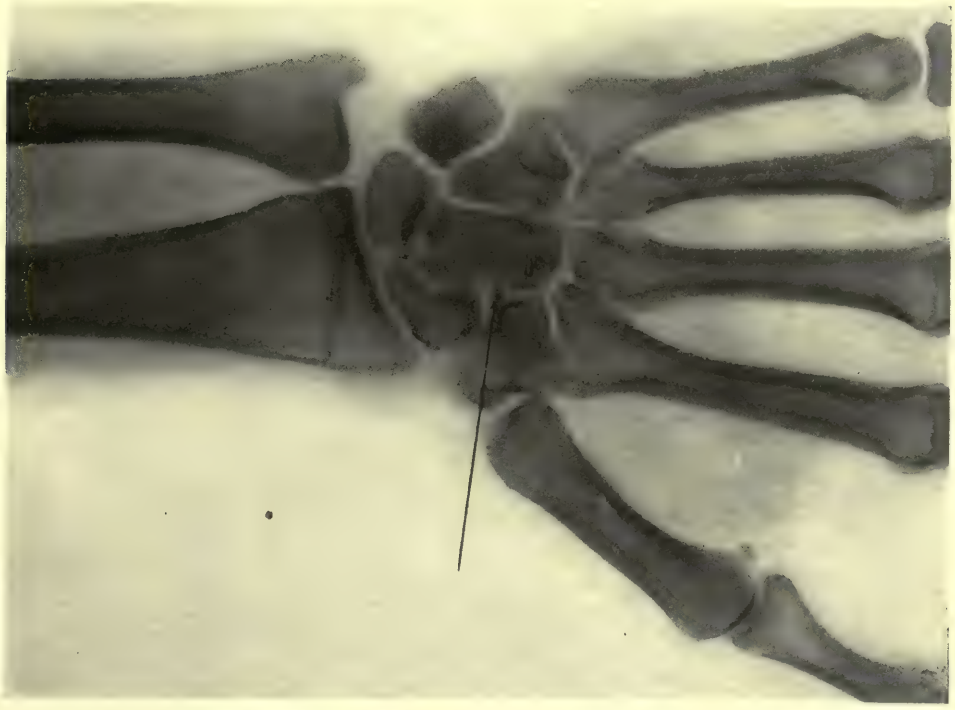

FIG. 11.

PLATE V.

FIG. 13. *Radiale externum.* C. 120, white, male, æt. 70. Left hand. This separate bone forming the tip of the scaphoid on the palmar aspect is 13 mm. long. It rested on the scaphoid by a nearly smooth surface which probably had once been covered by non-articular cartilage. There was no sign of fracture. The distal surface of the radiale externum helped to support the trapezium and apparently had been covered by articular cartilage. The somewhat pathological aspect which the bone presents was not evident before complete maceration. The right hand was not available.

FIG. 14. An *epilunatum* free. 440, white, male, æt. 61, the same whose right hand presented a divided scaphoid, shown in fig. 2. There is no sign of violence in this hand. The epilunatum is typically placed in the angle between the semilunar, scaphoid and os magnum, resting on the dorsum of the last. The greatest diameter nearly transverse is 6.5 mm. If this hand were X-rayed in the usual position of pronation it is unlikely that the outlines of this little bone would be recognized.

FIG. 13.

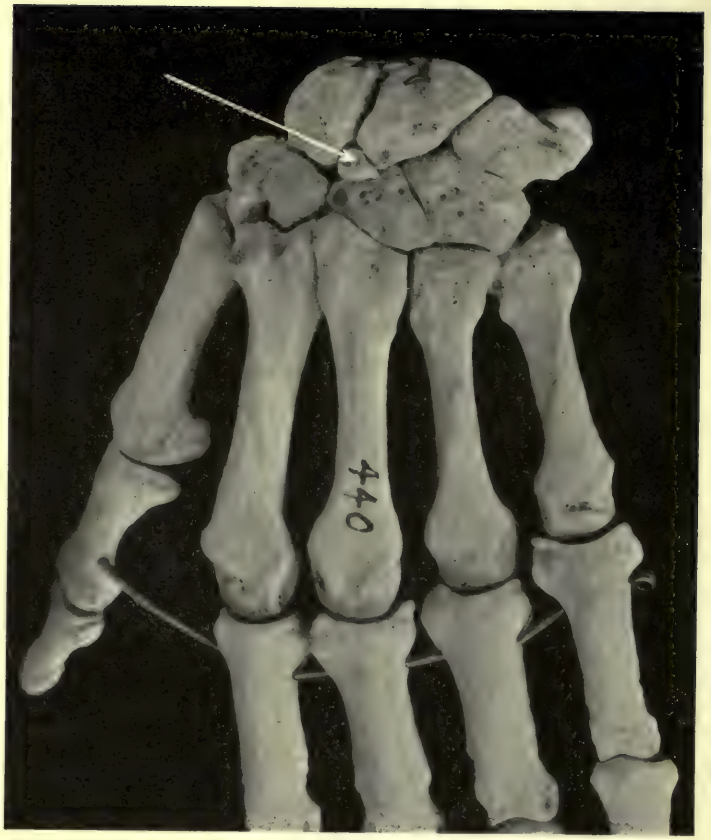

FIG. 14.

PLATE V.

PLATE VI.

FIG. 15. *Divided semilunar.* C. 109, male, white, æt. 74. This is an extremely puzzling case. There is a free bone on the dorsum representing probably more than a third of the semilunar. On the palmar side there is a well-marked hypolunatum fused with the semilunar. Two hypotheses present themselves: either there is a very large epilunatum, quite out of proportion to what is usually seen, or the bone is divided; and again this may have happened by an error in development or by violence. An interesting fact is that this is not an unique observation. Pfitzner inclined to attribute a similar condition to a fracture. This bone was coated with articular cartilage on its palmar side which played on the head of the os magnum. Its distal face which lies against the semilunar was probably connected with it by non-articular cartilage. On its ulnar side there was a true joint between it and the unciform. The latter rises at its distal end well above the level of the os magnum, so that this separate bone forms the central part of a bridge between the unciform and scaphoid above the magnum. This elevation has a rather pathological aspect, though the line of the joint seems normal. It is noteworthy that there is the opening on the dorsum of the scaphoid of a very large cavity in that bone. The other hand presented nothing noteworthy. I incline to think it an unusually large epilunatum which developed separately. The coating of articular cartilage on its palmar side and on that against the unciform do no agree with the theory of a fracture.

FIG. 16. Three *semilunar* bones. The two on the left have each a fused epilunatum. The one on the right presents a large cavity, probably connected with the entrance and exit of nutrient vessels. The occurrence of this cavity, which is occasionally observed, might in some cases account for such a division of the bone as occurs in fig. 15. In that instance, however, there was no sign of it.

FIG. 17. *Ulnare externum.* H. 175, white, male, æt. 63. This bone on the ulnar side of the wrist is one of the rarer occasional ones. I have never recognized it in a skiagraph, but one would expect it to show clearly. The specimen in this figure is a rather uncommonly large one. It appears sometimes as a knob on the cuneiform or unciform and might under these circumstances be seen in an X-ray. This hand has also a large *epilunatum* fused with the semilunar.

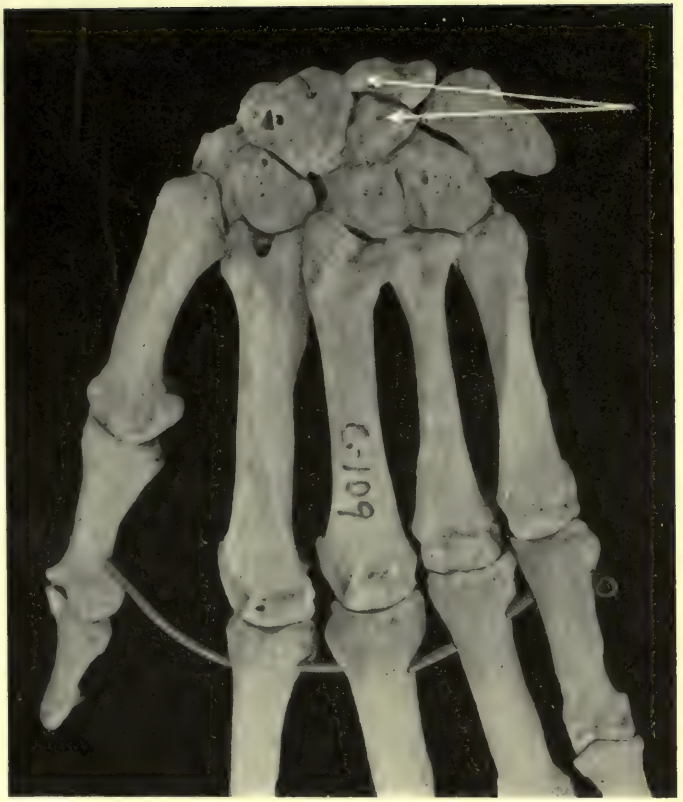

FIG. 15.

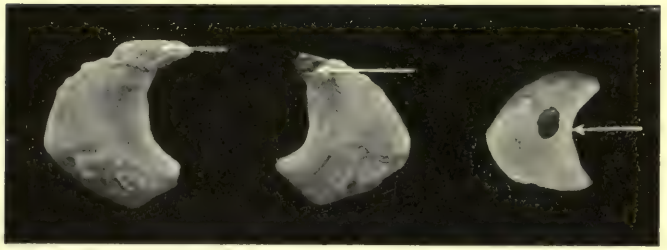

FIG. 16.

FIG. 17.

PLATE VI.

PLATE VII.

FIG. 18. *Secondary pisiform*, probably lost. 416, white, female, æt. 57. Left hand. Right hand normal. I believe that this bone has never been found distinct. The hand is a delicate and well shaped one, showing nothing pathological nor unusual excepting a surface on the dorsal proximal side of the pisiform which has the appearance of having had another bone connected with it by non-articular cartilage. Of course such a specimen is not conclusive but it is very suggestive. Such a bone should be seen in a skiagraph from the ulnar side.

FIG. 19. This is a pisiform with a fused *secondary pisiform*, the element thought to have been lost in the specimen presented in fig. 18. It is a bone of the right hand seen from the median side with the hand supine and pointing to the left.

FIG. 20. *Prætrapezium*. 587, white, male, æt. 75. The right hand has a free *prætrapezium* with articular cartilage between it and the trapezium. On the dorsum of the same hand there is an evident *centrale* fused with the scaphoid. The left hand has a *divided scaphoid* with much wearing away of one piece. The tendency to additional elements in this individual is shown by the persistence of the prætrapezium and centrale.

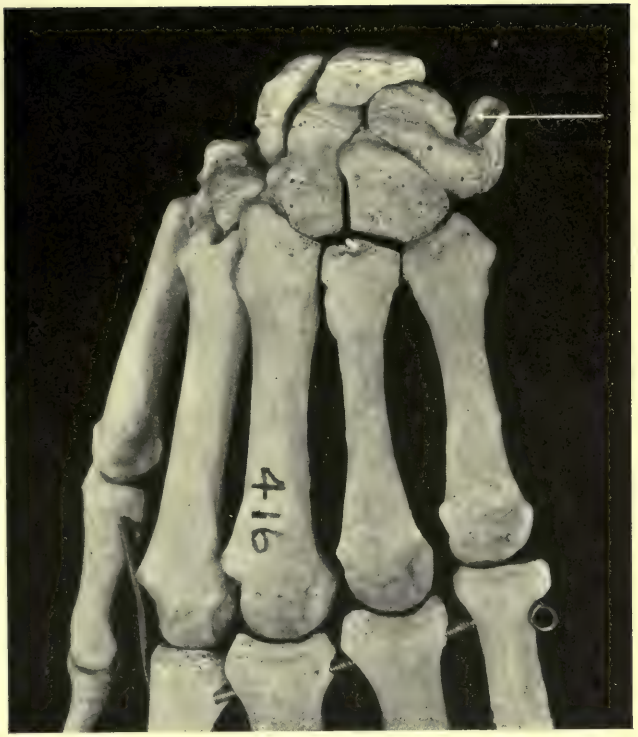

FIG. 18.

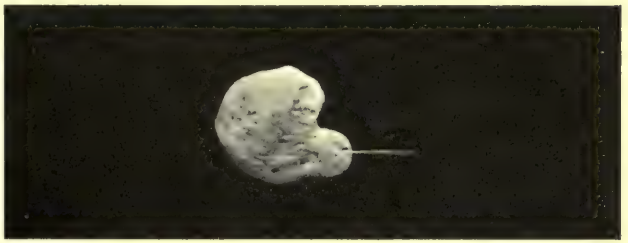

FIG. 19.

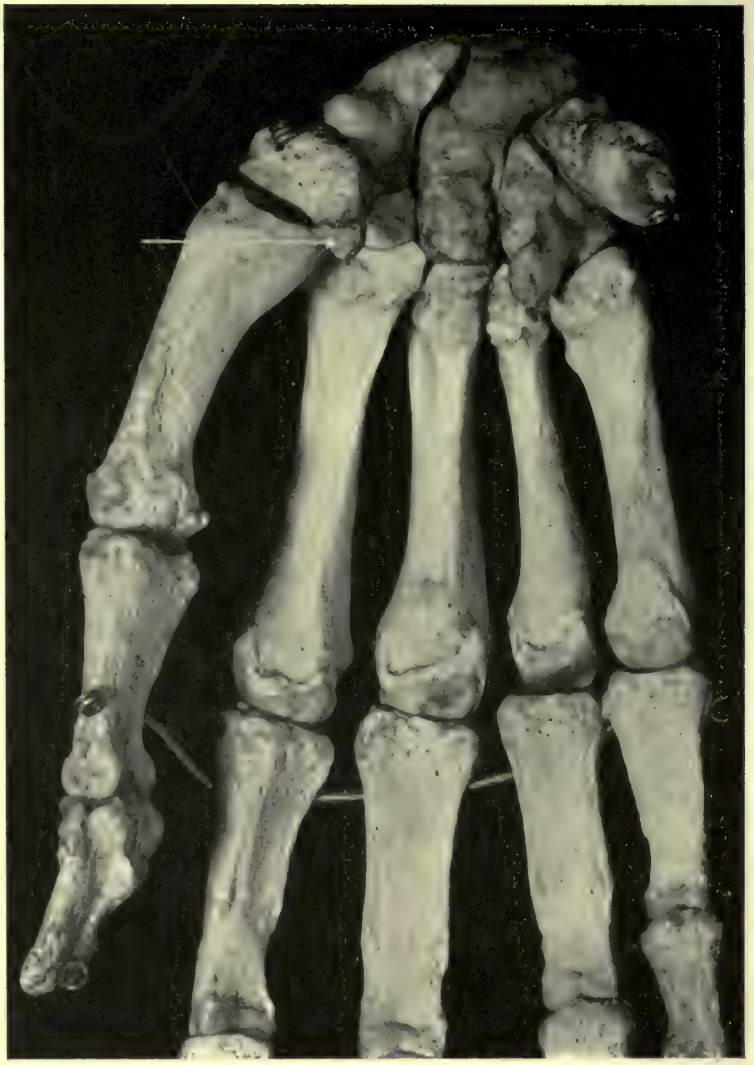

FIG. 20.

PLATE VII.

PLATE VIII.

FIG. 21. *Subcapitatum* distinct. 746, white, male, æt. 54. This bone, as is pointed out in the general section, had been predicted by Pfitzner and was found by the author after Pfitzner's death. It is an unique observation. The bone is present on both sides. There is (at least in one, and the description of the other is defective) a concave articular surface for the magnum and another for the third metacarpal. It is not likely that this bone is of any clinical importance, as, though the prominence might be detected by the X-ray, there is no way of knowing whether it is distinct or not.

FIG. 22. *Separate hamular process.* H. 386, white, male, æt. 52. Right hand. The overhanging part of the hamular process is distinct. There is no sign of violence nor of disease. The left hand is normal. Probably this could be detected by a skiagraph with the ulnar side of the hand against the plate.

FIG. 23. A series of unciform bones showing variously developed hamular processes.

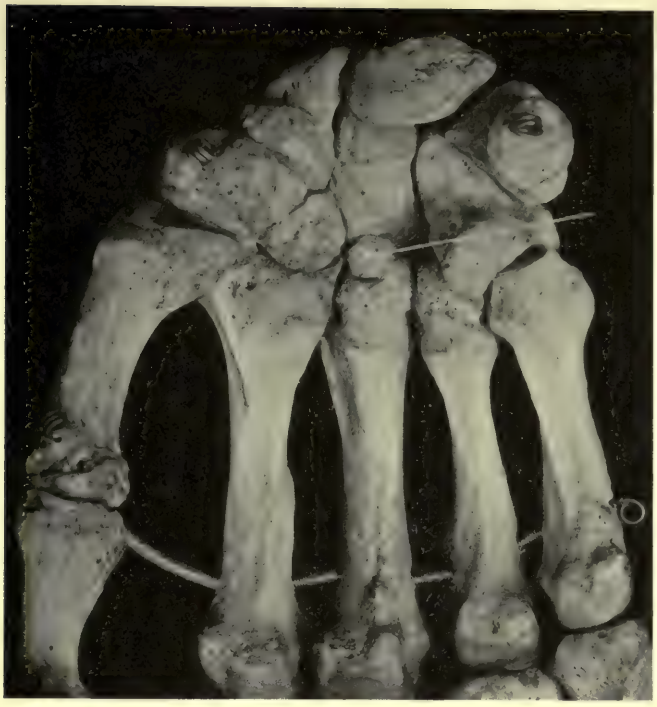

FIG. 21.

FIG. 22.

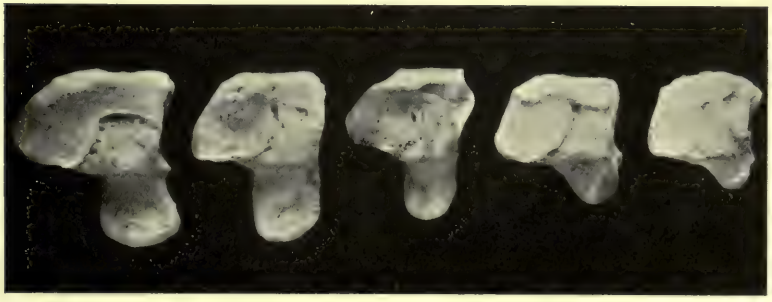

FIG. 23.

PLATE IX.

FIG. 24. *Styloid free.* 272, white, male, æt. 48. It is worth noting that the left hand shows a furrow across the concavity of the scaphoid, thus showing a tendency in the body to the separate growth of elements.

FIG. 25. A *separate styloid* in an X-ray. This shows quite as well as can be expected, when, as is usual, skiagraphs are taken with the palm against the plate. The only clinical application is that this should not be mistaken for a fracture. In doubtful cases the skiagraphs should be taken with the dorsum down.

FIG. 25.

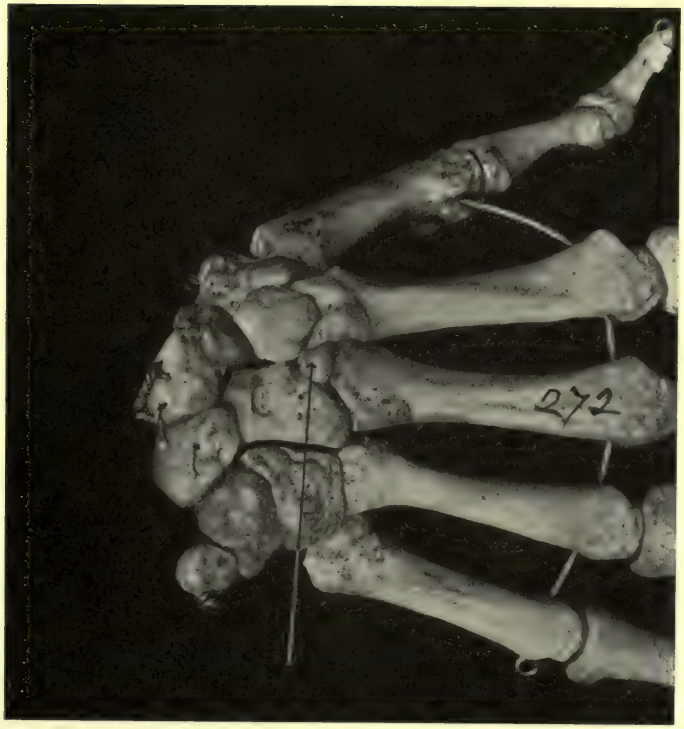

FIG. 24.

PLATE X.

FIG. 26. *Styloid fused with trapezoid.* 591, white, female, æt. 42. Both hands are practically alike. This condition is much the rarest of the possible combinations of the styloid. The conjoined trapezoid and styloid is very long transversely. It nearly conceals the ulnar prominence of the base of the second metacarpal known as the parastyloid.

FIG. 27. *Styloid fused with os magnum.* H. 278, white, male, æt. 29. The styloid of the right hand is fused with the os magnum, making the distal border of the latter approximately transverse. Such a condition should be recognized on an X-ray plate. The styloid of the left hand appears as a very large process of the third metacarpal. A good instance of this is seen in fig. 28.

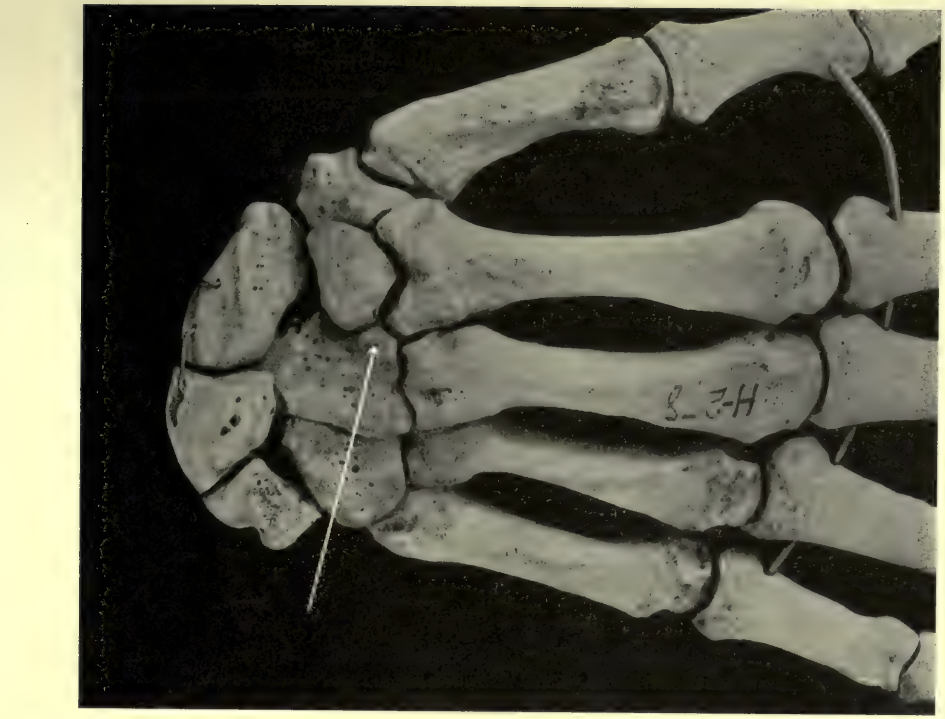

FIG. 27.

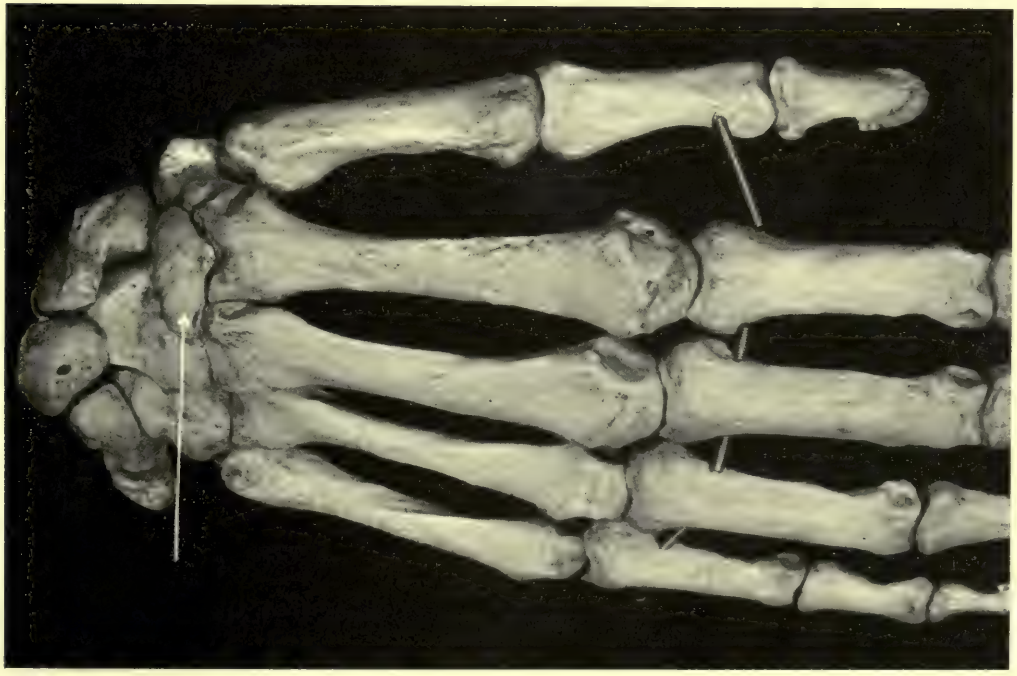

FIG. 26.

PLATE XI.

FIG. 28. *Fusion of semilunar and cuneiform.* H. 230, black, female; dorsal view. The condition of the other hand is unknown. There is a deep fissure on the distal surface extending into the palmar aspect.

FIG. 29. *Ditto.* H. 358, black, male, æt. 23. Left hand, palmar view. The fissure in the distal aspect, though deep in the middle, stops short of the borders.

This condition, which is found most frequently among blacks, should be clearly shown by the X-ray.

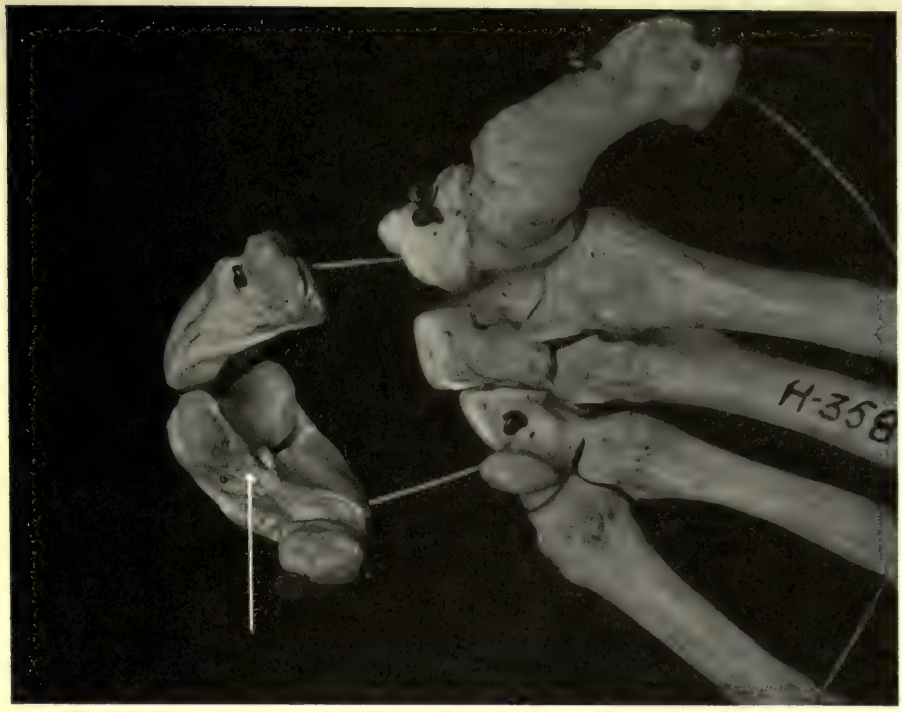

FIG. 29.

FIG. 28.

PLATE XII.

FIG. 30. Distinct *epiphysis* of proximal end of the second metacarpal. X-ray from a young person of 15. There is much uncertainty whether this is what is called a false epiphysis or a true one, or whether there is any sharp distinction between the two. What is remarkable is the tendency of this condition to present itself in this particular bone. In another year it would have fused with the shaft. There is a suggestion of a distal epiphysis on the first metacarpal.

FIG. 31. *Fusion of trapezoid and second metacarpal.* Left hand. Origin unknown. Surely female. The fusion extends through the whole thickness. Pfitzner had seen no true fusion and the "coalescence" he observed was limited to the dorsum.

PLATE XII.

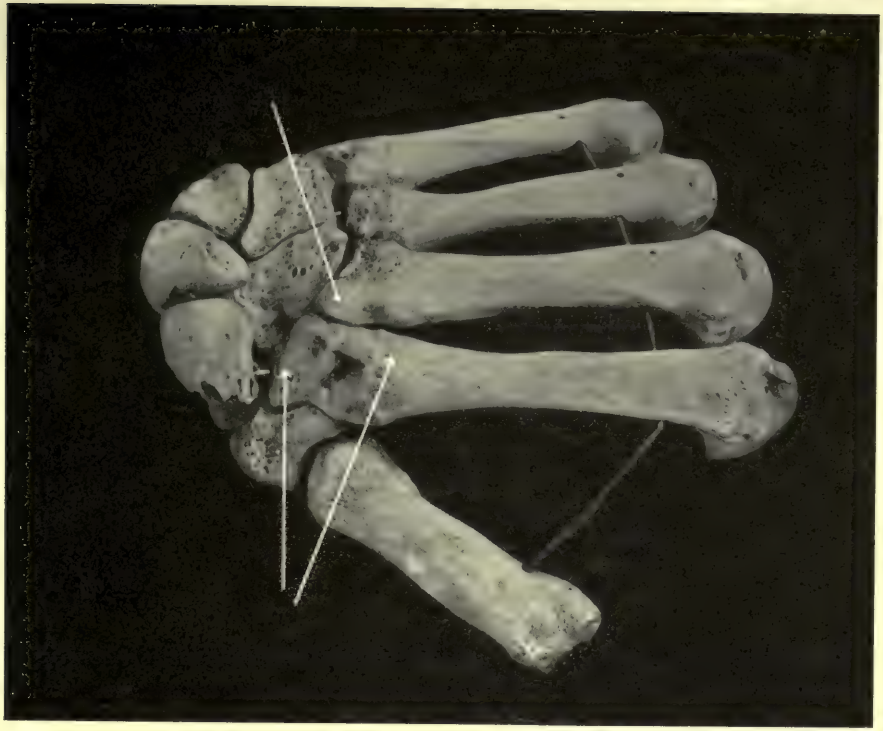

FIG. 31.

FIG. 30.

PLATE XIII.

FIG. 32. *Fusion of fourth and fifth metacarpals.* An X-ray from the hand of a boy of 18. Both hands were practically alike. Note the absence of the distal half of the fifth metacarpal.

FIG. 33. *Ditto*, only with very slight shortening of the fifth metacarpal. H. 265, white, male, æt. 26. Right hand. Nothing else is abnormal, but the hand is remarkably small. The articulated bones measure only 16.3 cm. The left hand and right foot were not examined. Nothing analogous was found in the left foot.

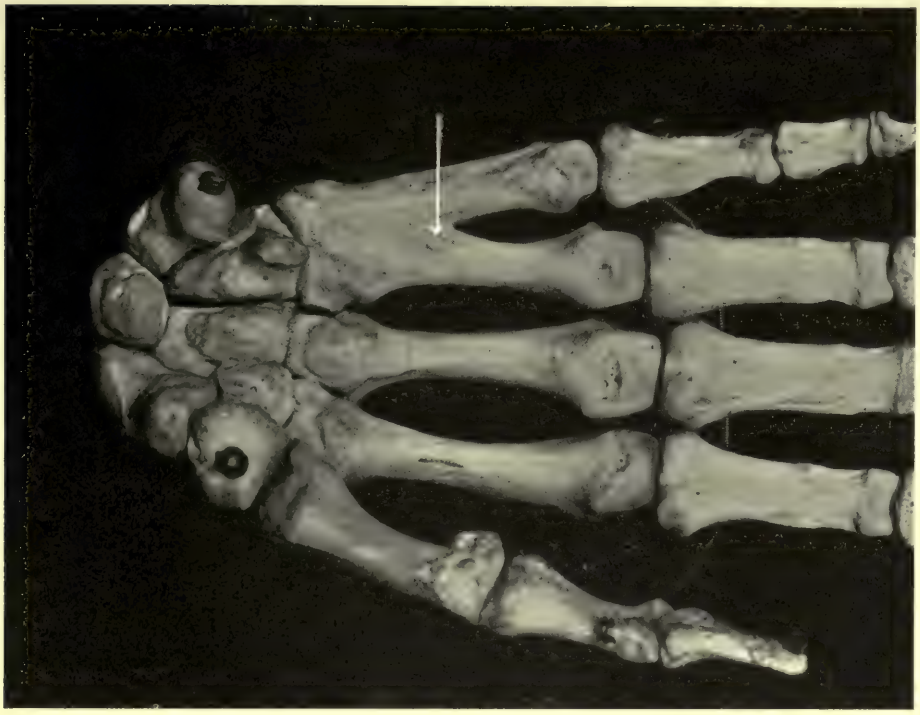

FIG. 33.

FIG. 32.

PLATE XIV.

FIG. 34. *Trigonum* single on left, double on right. C. 112, white, male, æt. 30. These are very large and very healthy feet from a man in the prime of life. There is no sign of lesion nor of disease. The left foot has a trigonum connected to the posterior process by cartilage. On the right the trigonum is double. Both pieces have the inferior surface covered by articular cartilage. They were joined by synchondrosis, the much larger internal piece overlapping the other. The larger piece was attached to the astragalus by a cartilaginous surface, the smaller apparently partly in the same way and partly by ligament. It is worth noting that the left hand of this body had a free *styloid*.

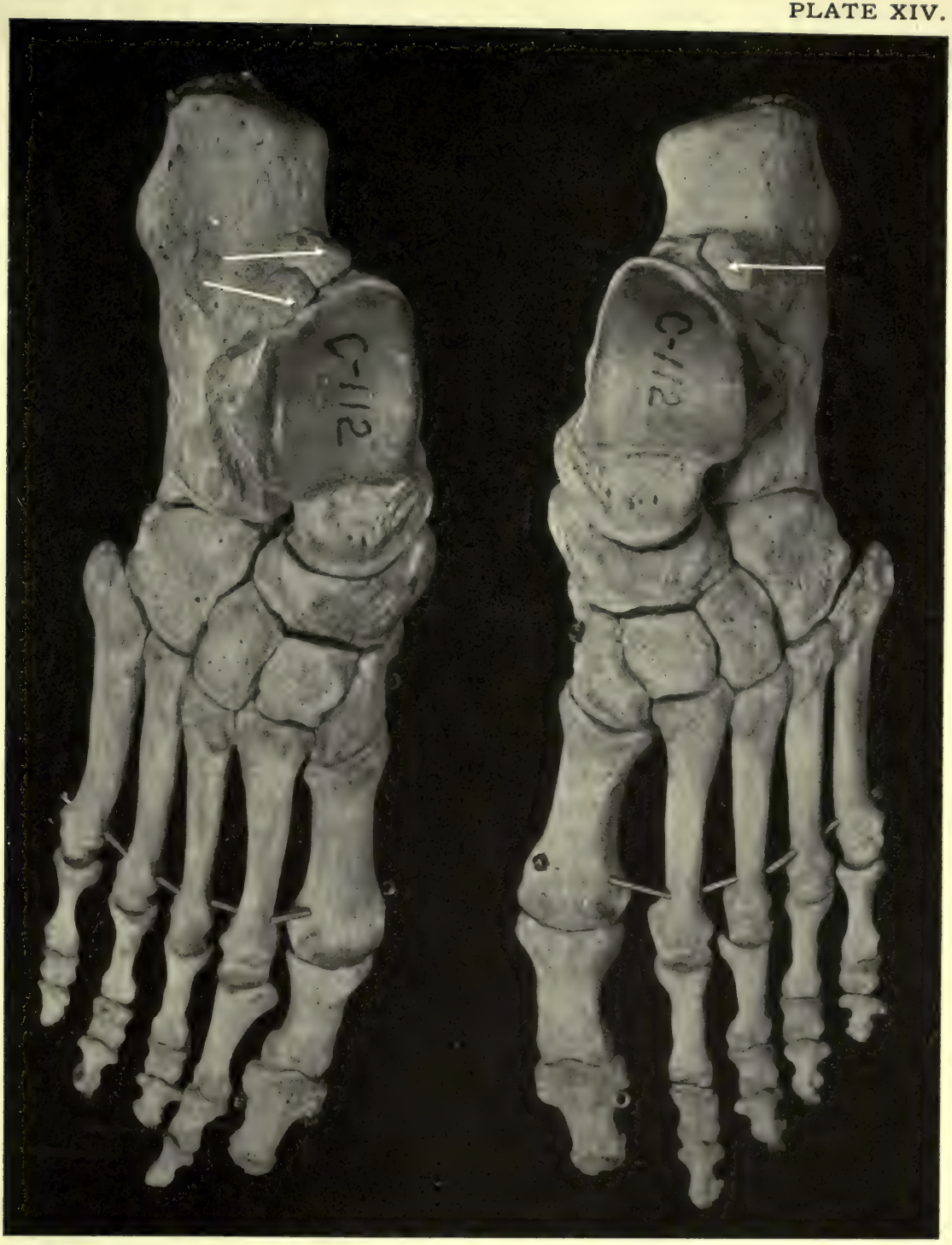

FIG. 34.

PLATE XV.

FIG. 35. *Trigonum* at end of long process. 629, female, white, æt. 40. The under side of the trigonum is beyond the articular portion of the process. There are no notes taken at the time of dissection, but the connection with the astragalus must evidently have been by cartilage or ligament. The bones show roughnesses at several points on the dorsum. There is no reason to believe this bone was the result of a fracture, but the possibilities of its being of pathological origin may perhaps be admitted. The lower arrow points at the normal relation of the outer end of the scaphoid in contradistinction to its synchondrosis with the os calcis shown in fig. 36.

FIG. 36. *Trigonum*. C. 122, white, male, æt. 30. Left foot. The feet are healthy but present several peculiarities. This side view is given for convenience of comparisons with X-rays. The trigonum is connected by cartilage. The process is well developed on the other foot. This foot presents also a synchondrosis between the os calcis and the scaphoid, and fusion of the second and third phalanges of the little toe. There was also a free intermetatarseum about 3 mm. in length which was lost. The right foot had a much broader synchondrosis between the os calcis and scaphoid, a very minute nodule in areolar tissue representing the intermetatarseum, and a normal little toe.

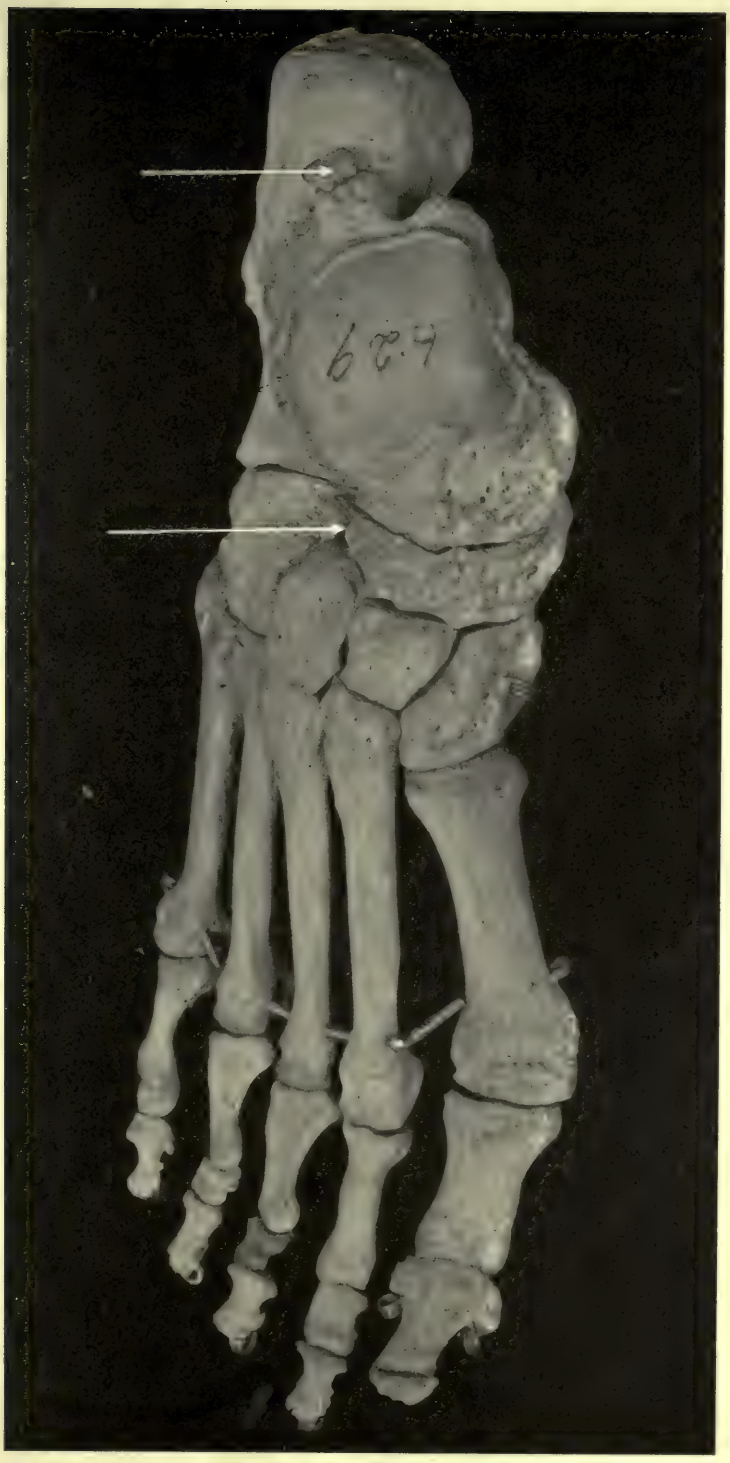

FIG. 35.

FIG. 36.

PLATE XVI.

Fig. 37. *Trigonum* shown by the X-ray taken of a leg amputated for chronic disease higher up, with no question of lesion of the foot.

Fig. 38. Fused *trigona* in both feet. H. 313, white, male, æt. 29. The larger trigonum on the left astragalus is almost free, that of the right is almost assimilated. There is no suggestion of injury.

FIG. 37.

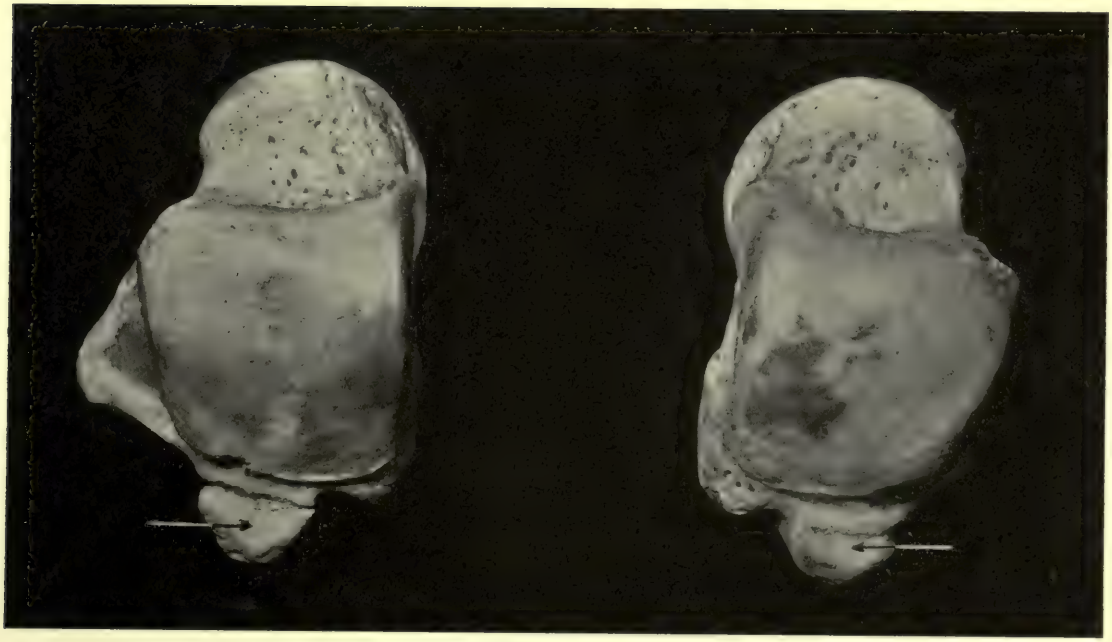

FIG. 38.

PLATE XVII.

FIG. 39. *Large internal process of astragalus.* H. 317, white, male, æt. 51. This is an exaggerated and hook-like internal tubercle. There is a furrow visible on the internal aspect as if separating it. The left foot presents no such peculiarity. A practical question is whether it would be possible to distinguish it by the X-ray from a trigonum. Possibly this might be done by taking a view of the foot from both sides.

FIG. 40. *Trochlear process near head of astragalus.* H. 211, white, male. Right foot. Left foot not examined. Though *a priori* one is inclined to call this process pathological, it does not present any roughness nor is there any sign of disease in the other bones. In another foot of unknown origin the process has a somewhat pathological appearance but, except for a tendency to flatness, the foot is otherwise healthy. This process shows very well in skiagraph.

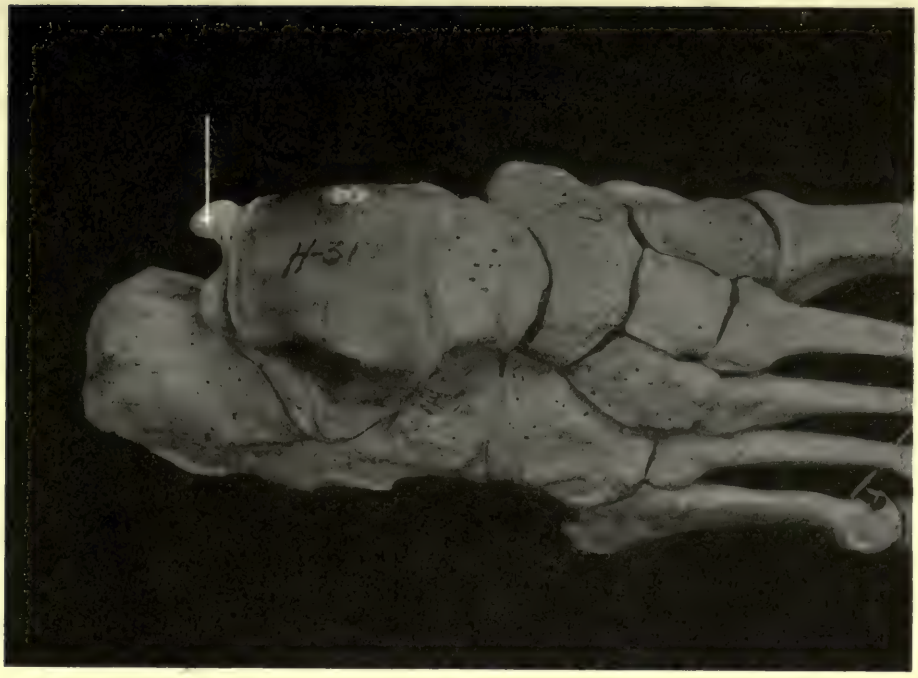

FIG. 39.

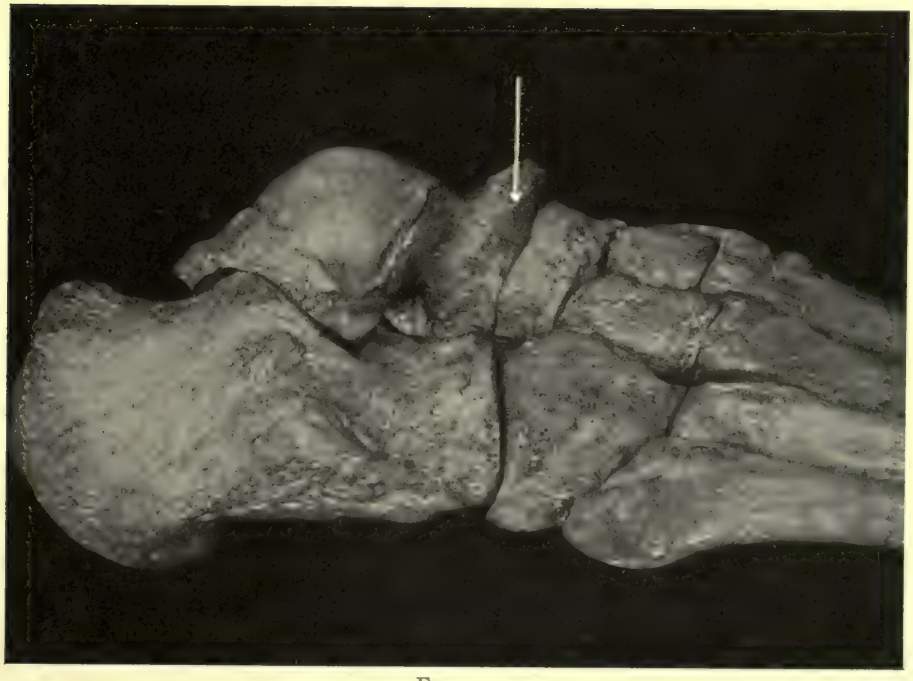

FIG. 40.

PLATE XVIII.

FIG. 41. Three astragali showing varying angle of inclination of the long axis of the head.

FIG. 42. Five astragali showing varying angle of lateral inclination of the neck.

FIG. 43. Five astragali showing varying development of external posterior process.

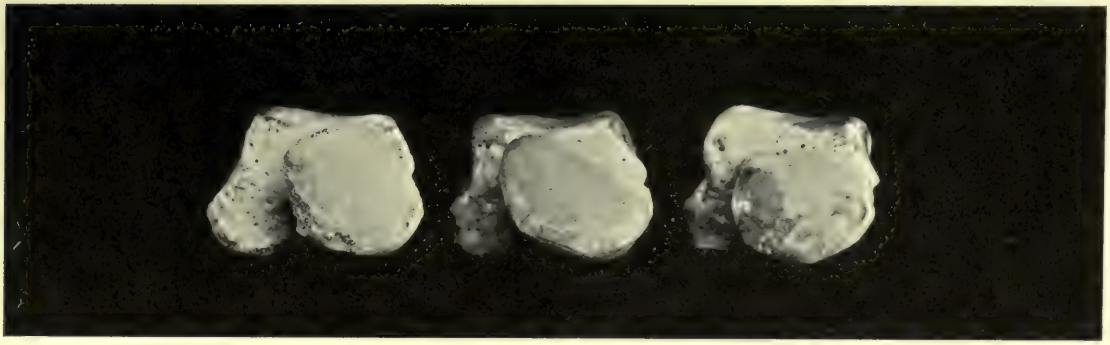

FIG. 41.

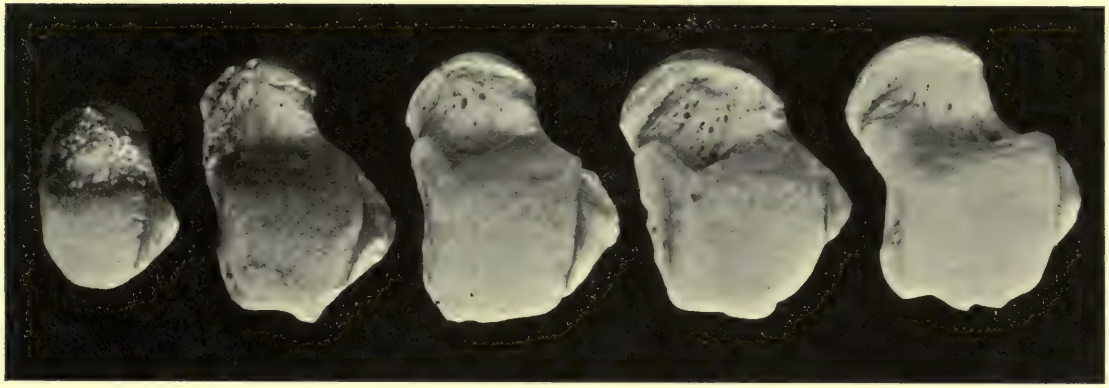

FIG. 42.

FIG. 43.

PLATE XIX.

FIG. 44. *Immense peroneal process of os calcis.* C. 117, black or mulatto, male, not past middle age. The process is very large on both feet, but somewhat larger on the left, where the upper aspect presents a flat, smooth facet on its outer border. The shape of the os calcis approaches that of the chimpanzee. Pfitzner figures a somewhat similar bone from the body of a young German woman. It is extermely rare. In both feet of this negro there is a large *tibiale externum* fused with the scaphoid and a trigonum so thoroughly fused as to be hard to recognize.

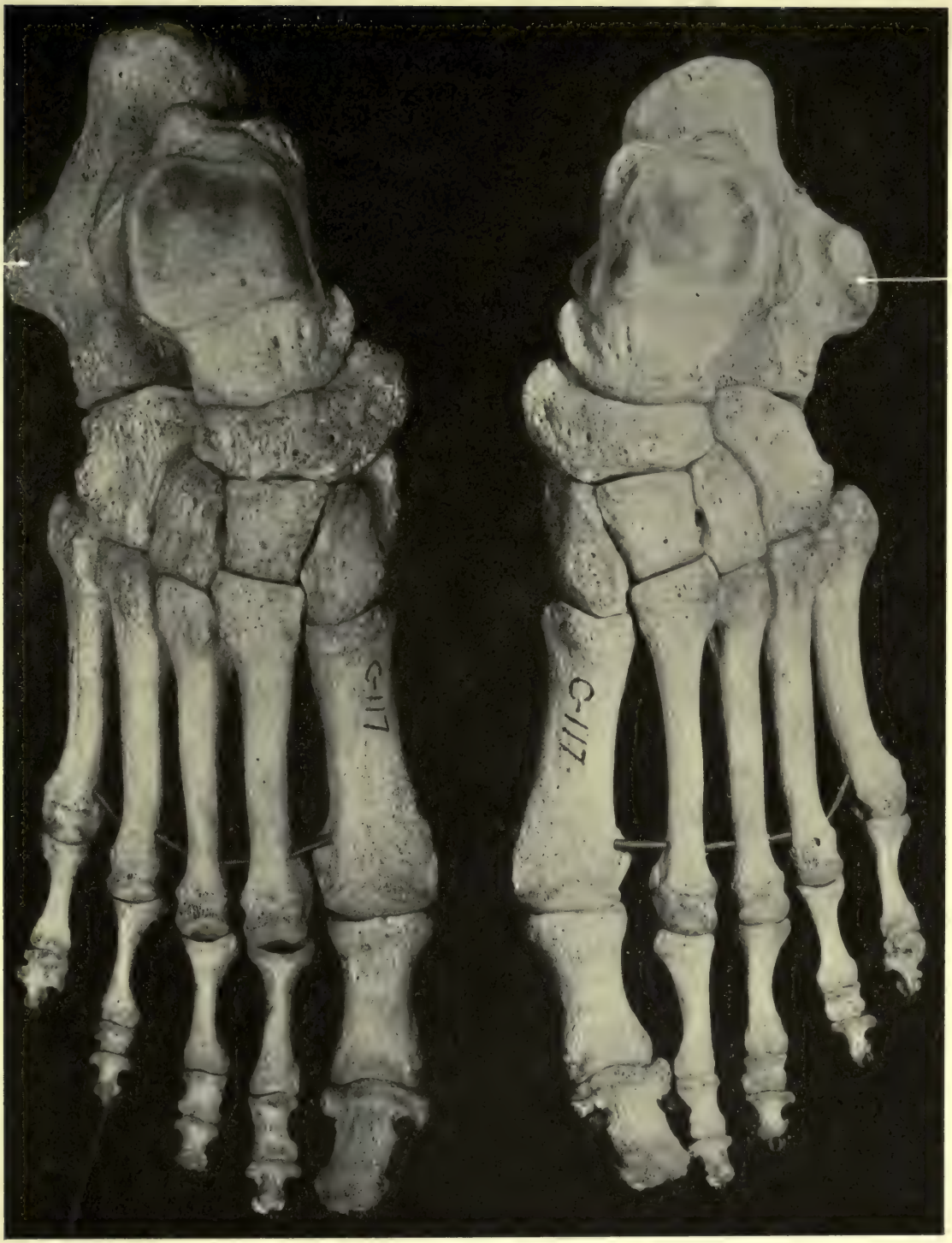

FIG. 44.

PLATE XX.

FIG. 45. Probably pathological development of the *peroneal process* of the *os calcis*. C. 85, white, male, æt. 62. Probably this overhanging curved plate of bone is for the most part due to ossification of fibrous tissue. In other places, however, the foot shows few signs of a similar condition. The left foot was not observed. This foot is, of course, radically different from the preceding one in which the process is not only larger, but thick and massive. It may be questioned, however, whether one form would be distinguished readily from the other in a skiagraph.

FIG. 46. Five *calcanea* showing from behind different inclinations of the bone and varying development of the plantar tubercles.

FIG. 47. Five *calcanea* (not the same as the preceding) showing on the plantar side the varying shape and development of the plantar tubercles.

FIG. 45.

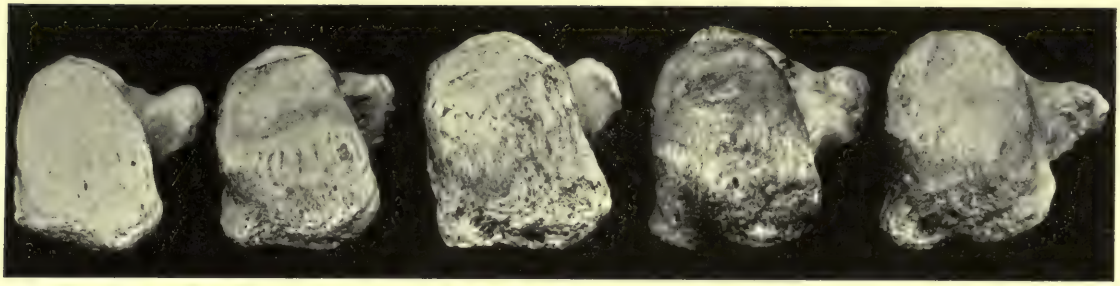

FIG. 46.

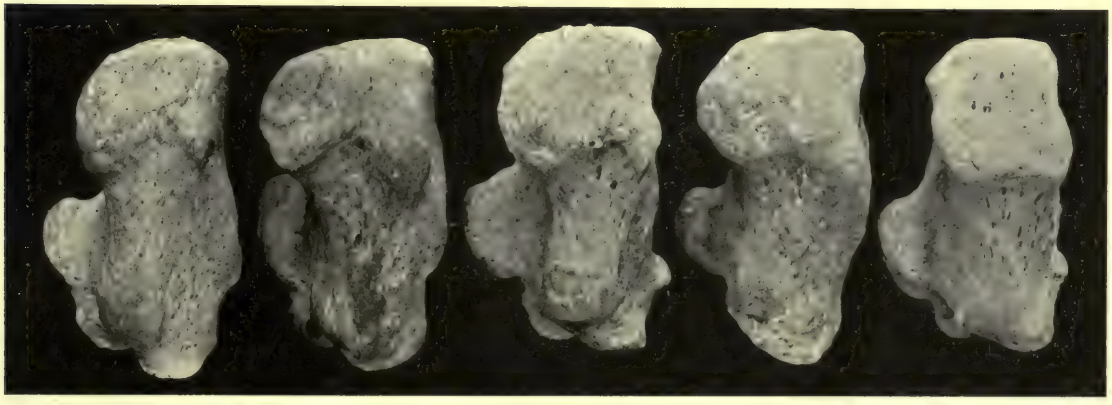

FIG. 47.

PLATE XXI.

FIG. 48. *Synchondrosis of os calcis and scaphoid.* C. 122, white, male. This is the mate of the foot presented in fig. 36, which showed a narrow strip of synchondrosis between the os calcis and the scaphoid. On this side it is much broader, measuring about 1 cm. at the dorsum, which is as broad as it is often found. The os calcis shows also a rather large peroneal process.

FIG. 49. *Ditto.* C. 160, white, male, æt. 22. The skiagraph was taken when the foot had been only superficially dissected.

FIG. 48.

FIG. 49.

PLATE XXII.

FIG. 50. *Secondary os calcis.* These skiagraphs are those of a woman who hurt her left foot falling from the edge of the bath-tub. The diagnosis of fracture was made after that of the left foot had been taken, especially as there was tenderness in the dorsum over the point in question. A skiagraph of the right foot showed, however, that there was an extra bone at this point in both feet. The left foot is at the reader's right.

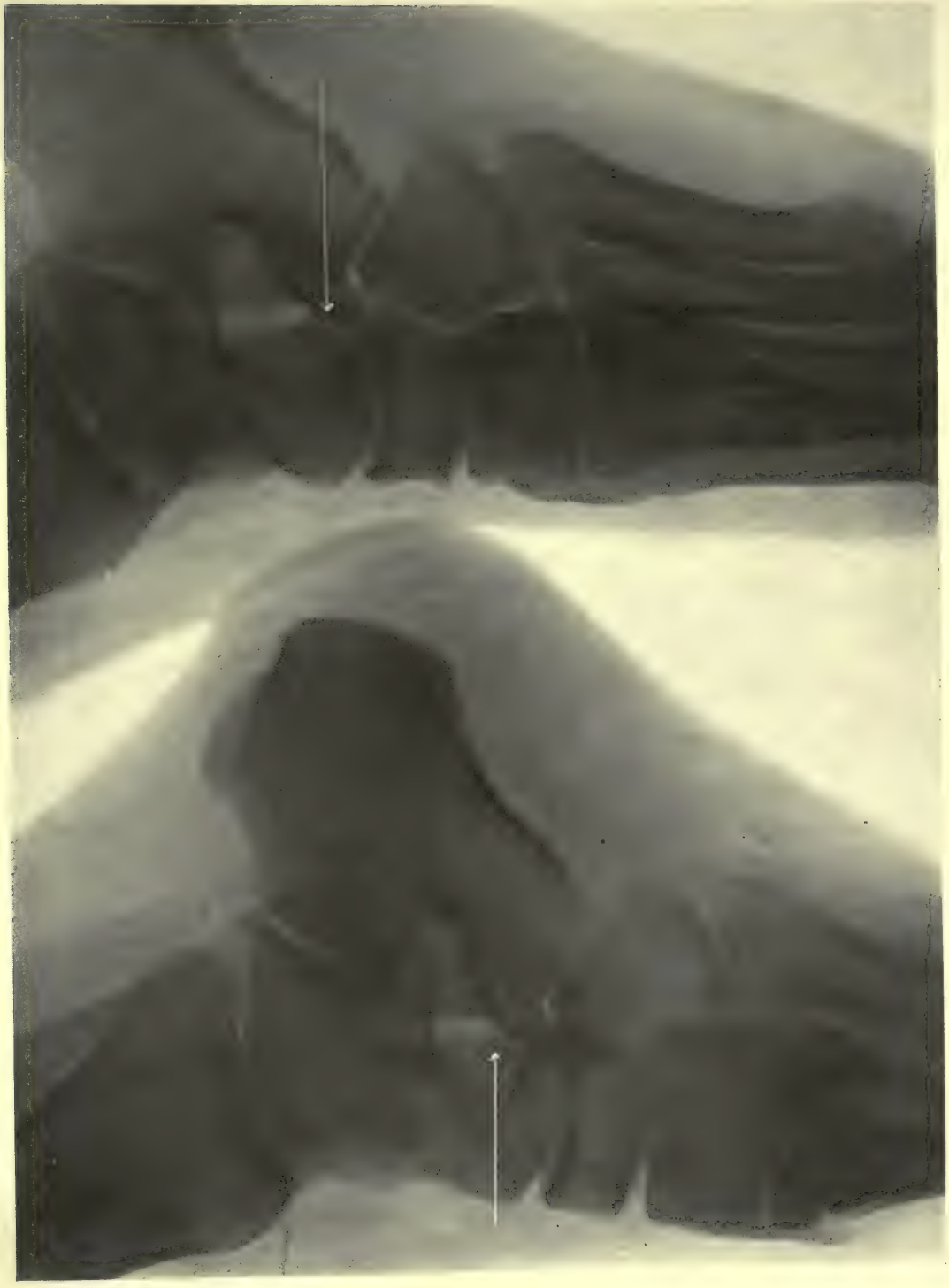

FIG. 50.

PLATE XXIII.

FIG. 51. *Secondary os calcis.* 226, white, male. The small nodule is shown in the plate. Unfortunately the way in which it is connected with the bone below it, whether by joint, cartilage or ligament, is not noted. It was not found in the left foot. It is very common in skiagraphs of the outer side of the foot to see a projection of the os calcis in this direction, which if marked would go on to join the scaphoid. It is very difficult to determine how much of this effect is due to bone and how much to the position of the plate. In this foot the plantar end of the third cuneiform was united to the matatarsal by synchondrosis. Another form of *secondary os calcis* is shown in fig. 64.

FIG. 52. *Tibiale externum.* This foot is surely male, but its origin is unknown. A large *tibiale* is placed between the scaphoid and the sustentaculum. It evidently was joined to the former by synchondrosis. The same foot has a good specimen of an *intermetatarseum* fused with the internal cuneiform.

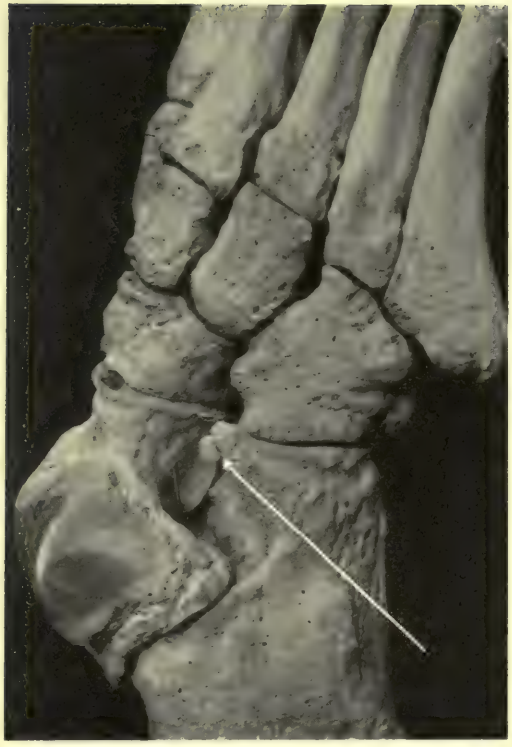

FIG. 51.

FIG. 52.

PLATE XXIV

FIG. 53. *Ditto.* 640, white, male, æt. 45. The tubercle of the scaphoid is so large and projecting in this case that it might very well pass for a fused *tibiale externum*, but it bears a small bone projecting from it outward and backward. There seems to be a special facet for it; but whether it was joined to the scaphoid by cartilage or glided on it in the tendon of the posterior tibial must remain uncertain.

FIG. 54. *Ditto.* H. 252, female, white. The tibiale externum is fused to the back of the tubercle of the scaphoid so as to form a hook.

FIG. 53.

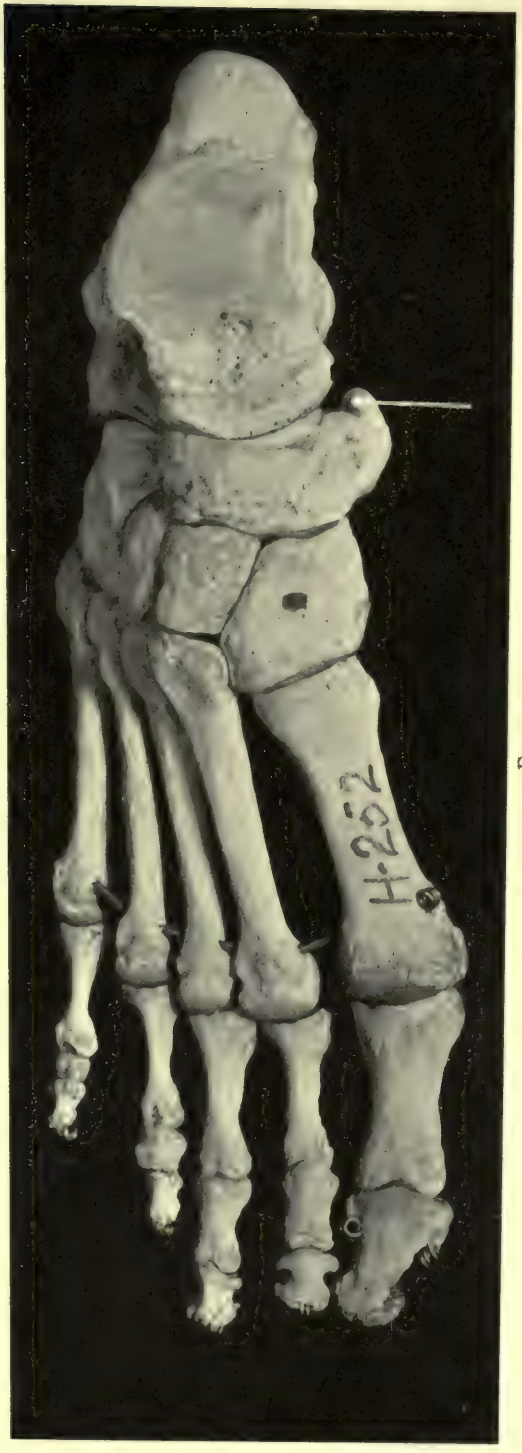

FIG. 54.

PLATE XXV.

FIG. 55. X-ray of *tibiale externum* in the style of that shown in fig. 52.

FIG. 56. *Ditto* of one resembling that shown in fig. 54.

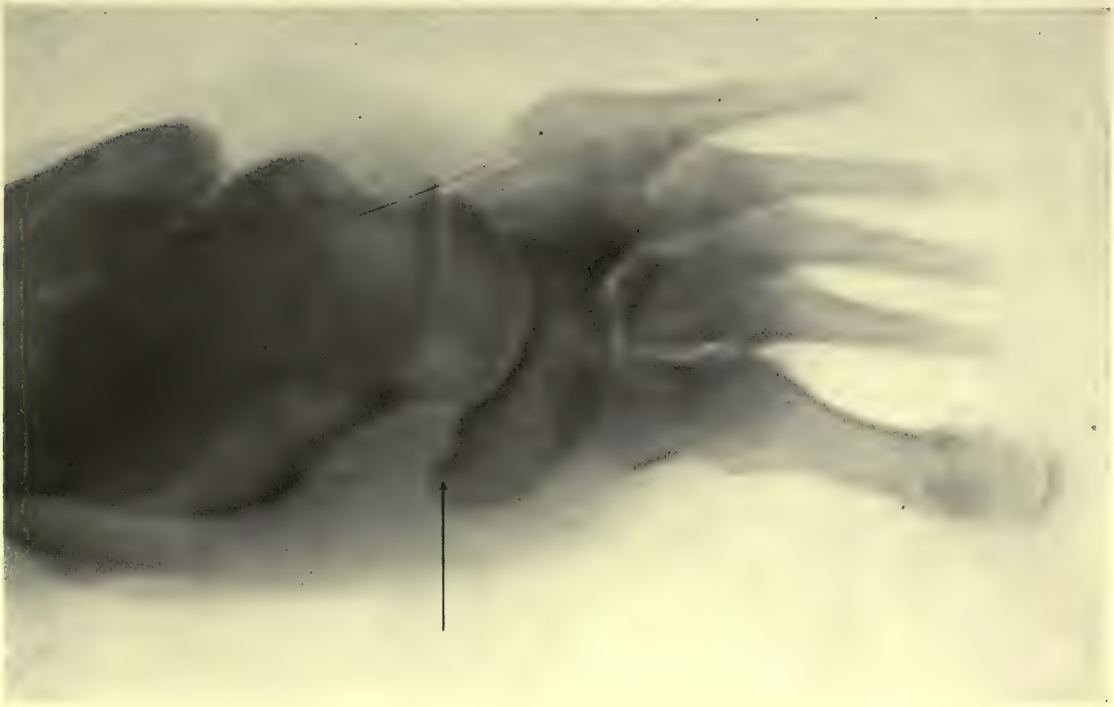

Fig. 56.

Fig. 55.

PLATE XXVI.

Fig. 57. *Secondary cuboid* fused with scaphoid. Origin unknown, but surely male. It is highly probable that this bone was once free and became fused with the scaphoid in later life. The dorsal aspect of the foot, particularly of the scaphoid, is pathological, but the sole may be called healthy. The upper part of this bone was cartilage-coated, forming a part of the socket for the head of the astragalus. It would seem as if so strong a bone should be recognized by the X-ray.

Fig. 58. *Ditto.* The origin of the specimen is unknown, but the bone is unmistakable though not so clearly marked off from the scaphoid as the preceding one. It is more vertically placed, bending but very slightly under the head of the astragalus. It is more striking than any in the following figure. (Fig. 65 should be studied in this connection.)

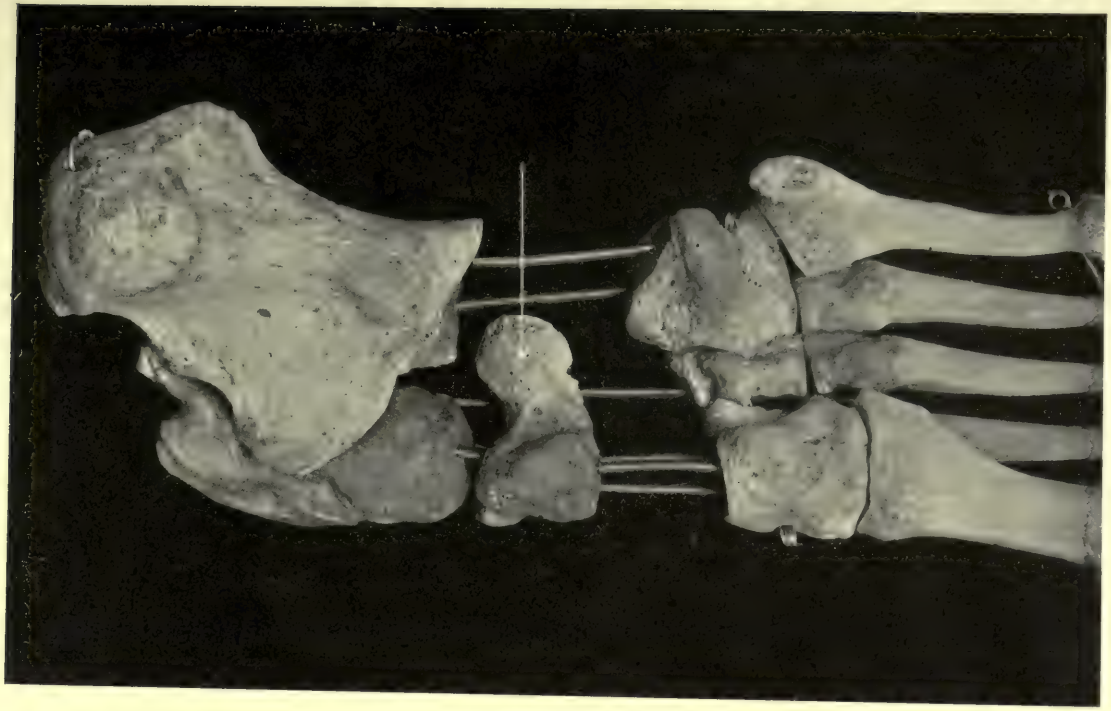

FIG. 58.

FIG. 57.

PLATE XXVII.

FIG. 59. Five scaphoids showing the varying development of the *secondary cuboid*, which is absent in the first bone and strong in the last.

FIG. 60. Five scaphoids showing the varying development of the *tibiale externum* which is small or wanting in the first and large in the last.

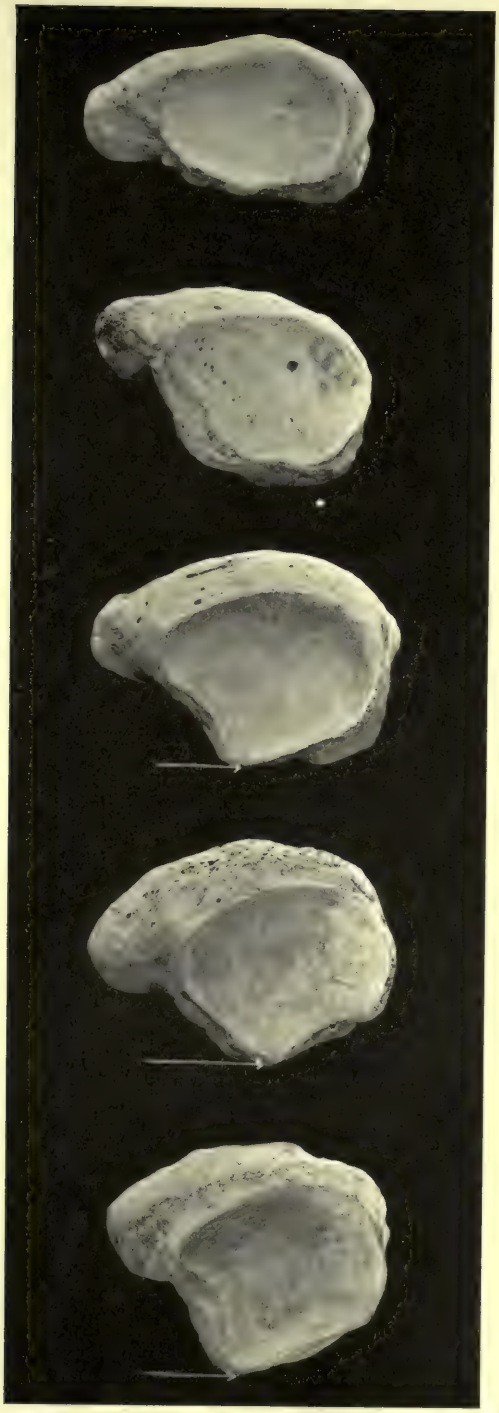

FIG. 59.

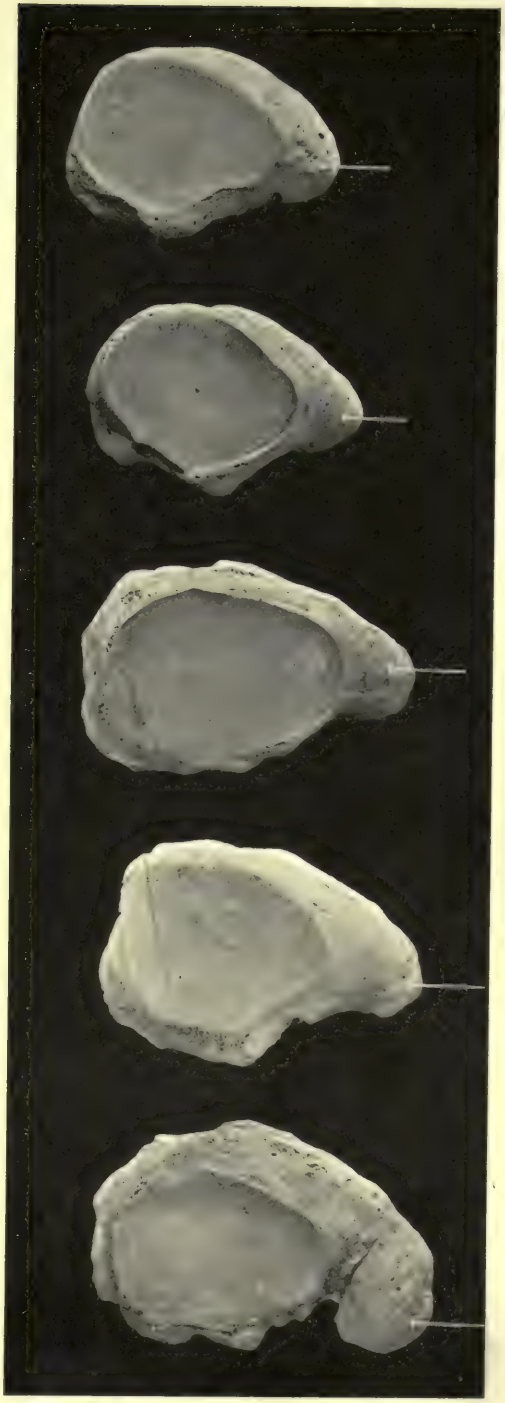

FIG. 60.

PLATE XXVIII.

FIG. 61. *Divided internal cuneiform.* This X-ray is that of a foot of a little girl of two years. The study of the plate and the next one shows an extra bone among the cuneiforms which can be explained only as a division of the internal one. There was no history of injury, but the foot had been sore for about a month when X-rayed at the hospital.

FIG. 62. Side view of the same, showing also ossification beginning in a *tibiale externum.*

FIG. 61.

FIG. 62.

PLATE XXIX.

Fig. 63. *Intercuneiform.* White, male, æt. 54. This figure and the next (which have appeared in the Anatomischer Anzeiger) represent the only instances of this bone.

Fig. 64. *Ditto.* White, male, æt. 60. Skiagraphs often suggest an *intercuneiform*, but the outlines of the bones, owing to the arch of the foot, are so complex in this region that there is great danger of error. I have never seen one in an X-ray which I dared to accept. This foot shows also a *secondary os calcis* of a different type from that shown in fig. 51.

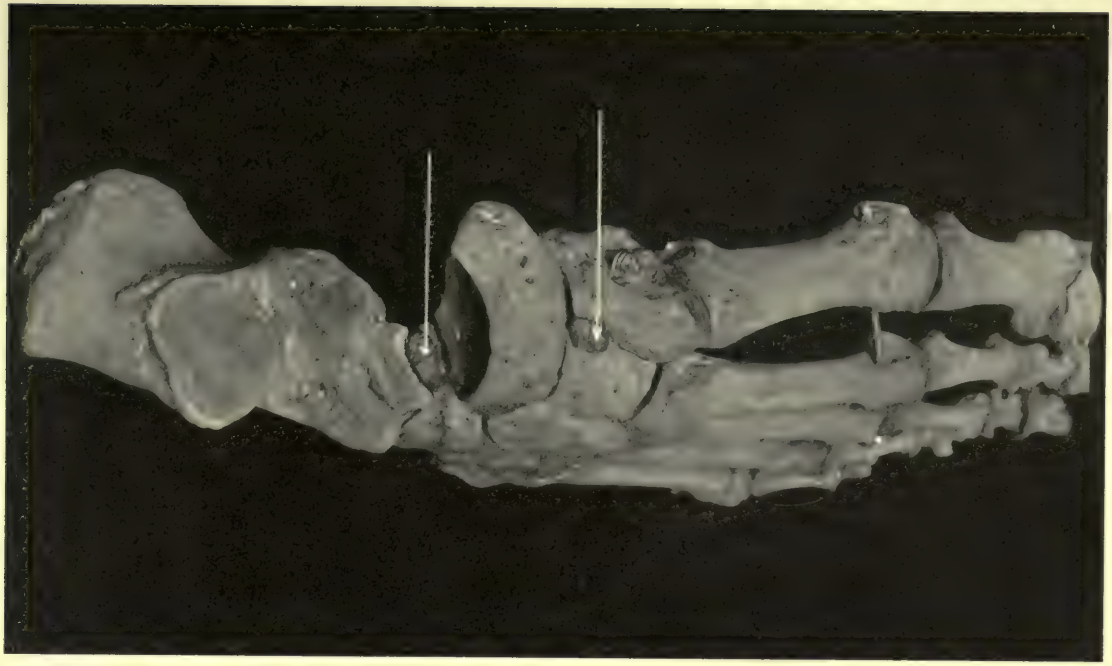

FIG. 64.

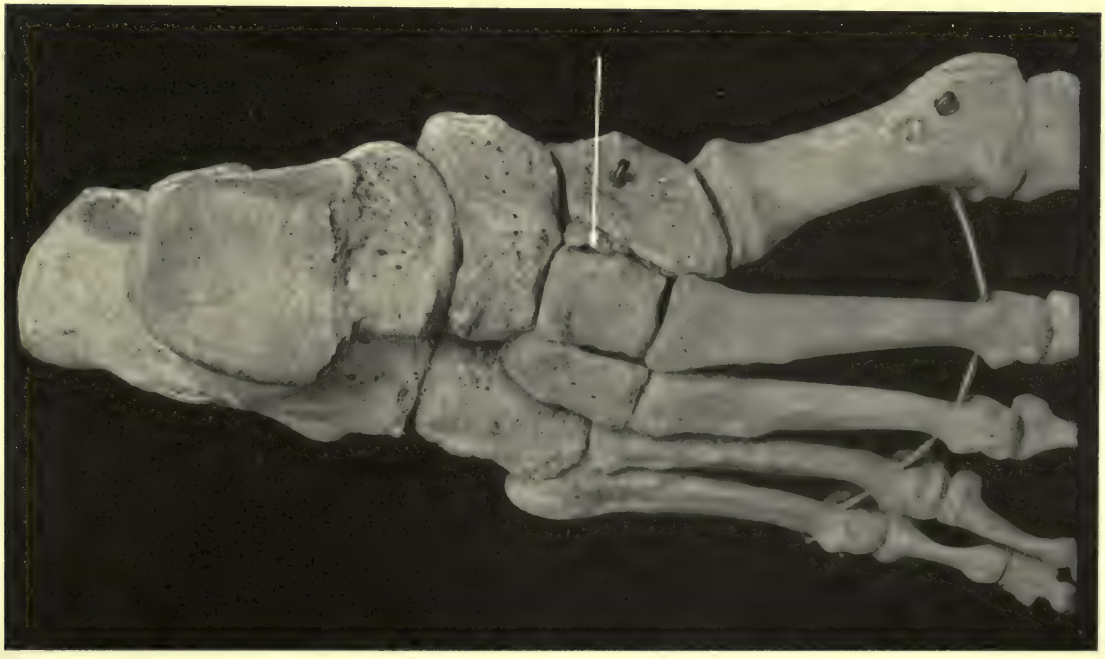

FIG. 63.

PLATE XXX.

FIG. 65. *Synchondrosis of scaphoid and cuboid.* 522, white, male. On the plantar aspect the scaphoid considerably overlaps the cuboid by a projection which very probably is the *secondary cuboid* fused with the scaphoid. The inferior part of the opposed surfaces has the characteristic appearance of one joined to non-articular cartilage. (This foot has also an *intermetatarseum* fused with the first metatarsal.)

FIG. 66. X-ray of the *peroneum*, commonly known as the sesamoid in the tendon of the peroneus longus.

PLATE XXX.

FIG. 66.

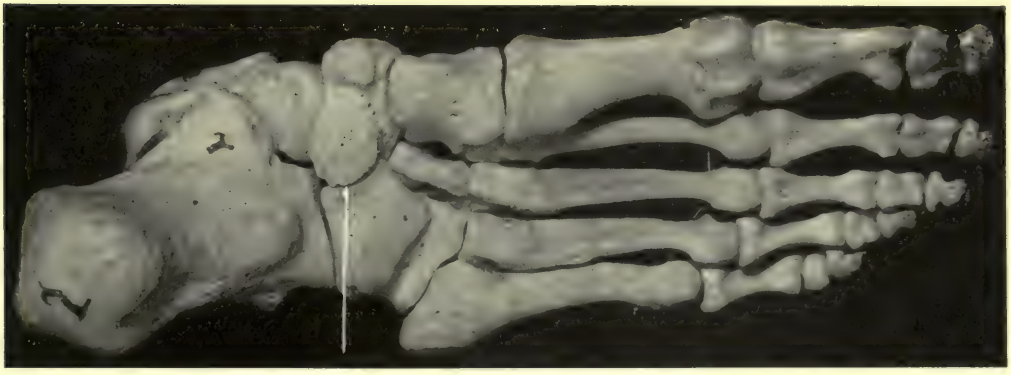

FIG. 65.

PLATE XXXI.

FIG. 67. *Peroneum.* 540, white, male, age unknown but probably advanced. The peroneum is remarkably large, being very nearly 2 cm. in length and more than half as broad. A part of its size, however, is due to the extension of ossification from its convex surface into the fibrous tissue.

FIG. 68. *Ditto.* An X-ray of the preceding foot taken before dissection.

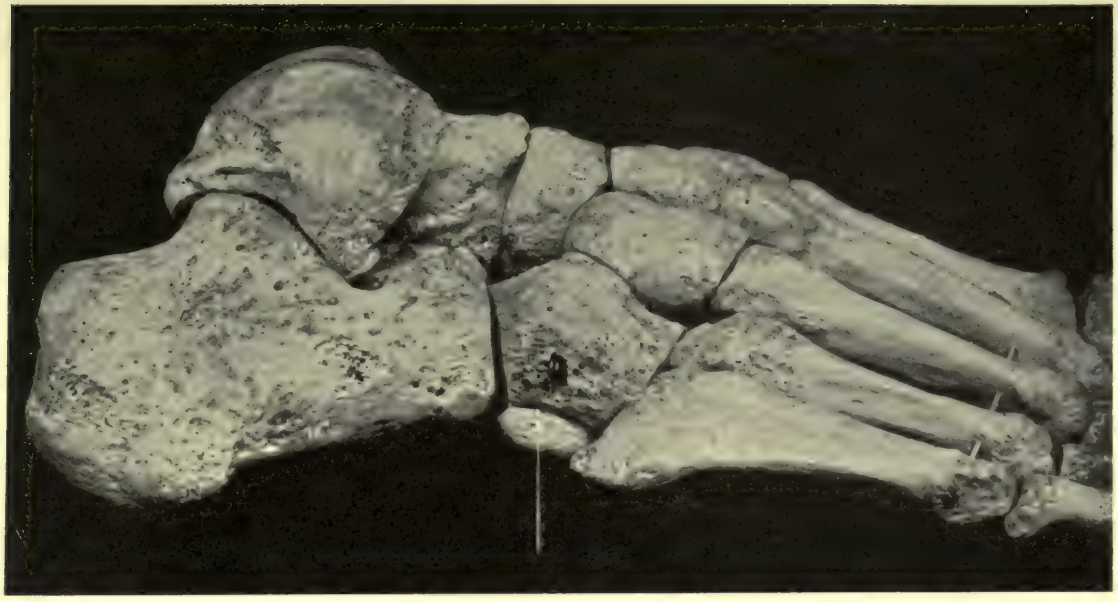

FIG. 67.

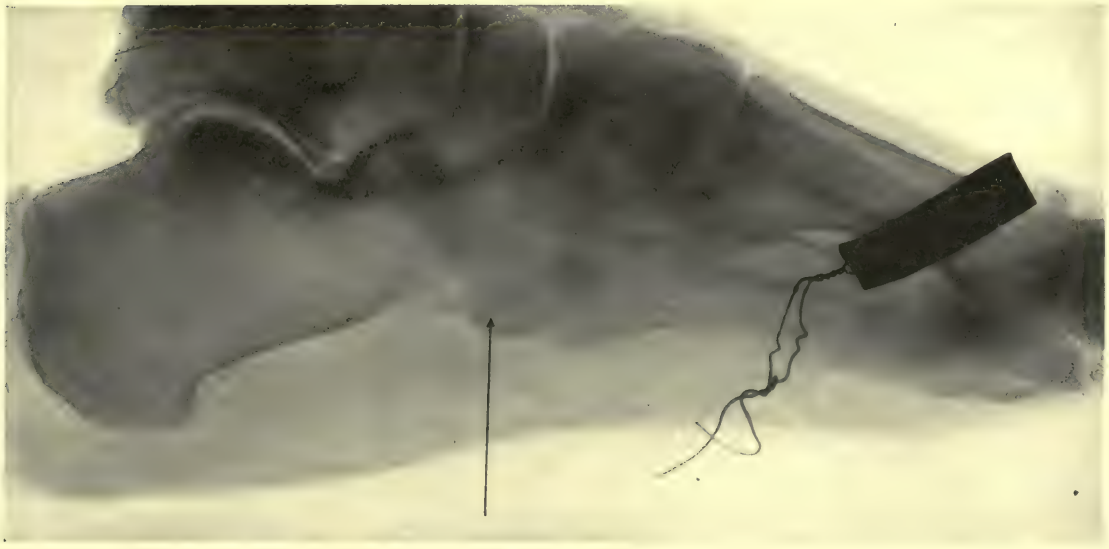

FIG. 68.

PLATE XXXII.

FIG. 69. *Intermetatarseum.* 424, white, female, æt. 66. The bone is *free* in both feet, which are practically similar. The bone of the left foot has three true articular surfaces for the internal cuneiform, the first and second metatarsals respectively. On the bone of the right foot the surface for the second metatarsal may not present true articular cartilage, but rather the imitation of it, so to speak, which is found against a bursa.

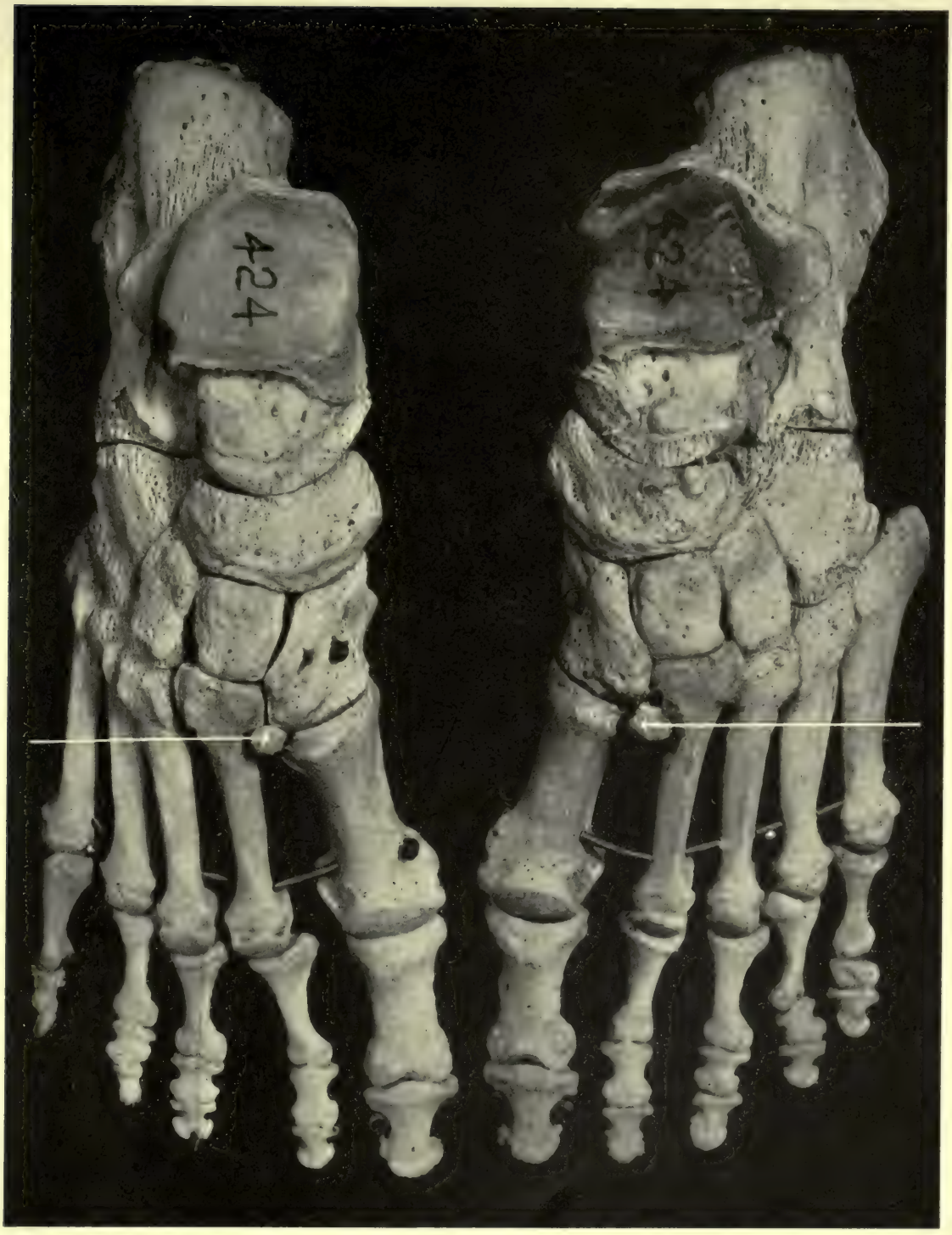

FIG. 69.

PLATE XXXIII.

FIG. 70. *Ditto.* Male foot of unknown origin; the same that appears in fig. 52. The intermetatarseum is *fused with the internal cuneiform.* This is the most common condition of this occasional bone. This foot has also a free tibiale externum and a secondary os calcis fused with the main bone.

FIG. 71. *Ditto.* Female foot of unknown origin. The intermetatarseum is *fused with the second metatarsal.* There is a remarkable resemblance between different specimens of this condition. The bone almost always has a pathological look and suggests an exostosis. In this case, however, the foot as a whole is in quite as healthy a condition as is commonly seen.

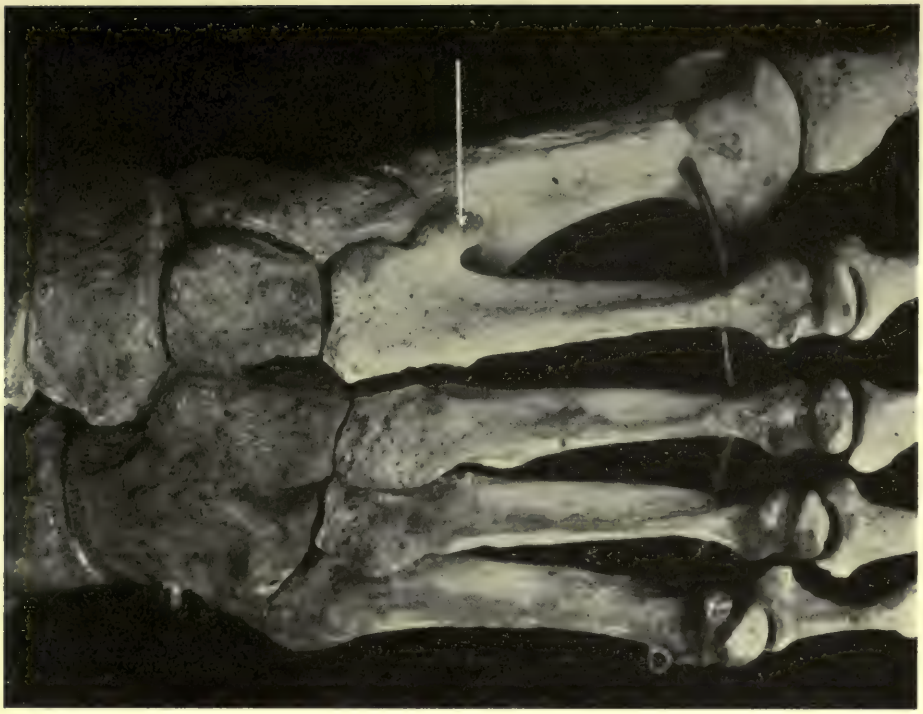

FIG. 71.

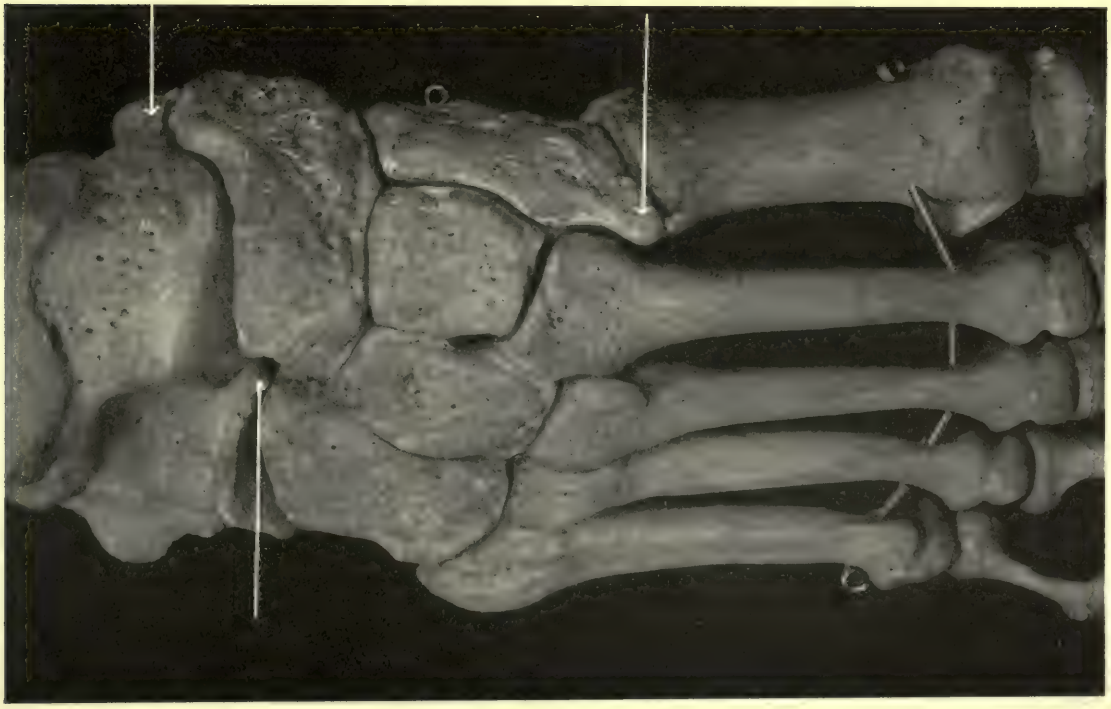

FIG. 70.

PLATE XXXIV.

FIG. 72. *Ditto.* 522, male, white. Intermetatarseum *fused with the first* metatarsal on the left foot. The bone projects proximally from the dorsum of the metatarsal, articulating with a special facet on the internal cuneiform and touching no other bone. The articular surface on this bone is separated by a cleft from that of the base of the metatarsal. This is the rarest condition of this bone, and this specimen the only one which I have seen. On the right foot of this body the bone was fused with the internal cuneiform. This foot appears in fig. 65.

These four figures show all the possible combinations of this bone. I have seen it once in an X-ray, but was not sure of it at the time. It was found on the foot when it was subsequently prepared. The lines of a skiagraph are very confusing in this region.

FIG. 73. *Fusion of the external cuneiform with the third metatarsal.* 601 (old number), white, female, æt. 19. This was the age given, but it was thought that the body was of a person some years older. Be this as it may, synchondrosis and beginning synostosis were observed by Pfitzner at the age of seventeen. This instance is a perfectly typical one. The foot is absolutely healthy and the fusion is only at the plantar end of the joint. This condition would not be easy to recognize by the X-ray.

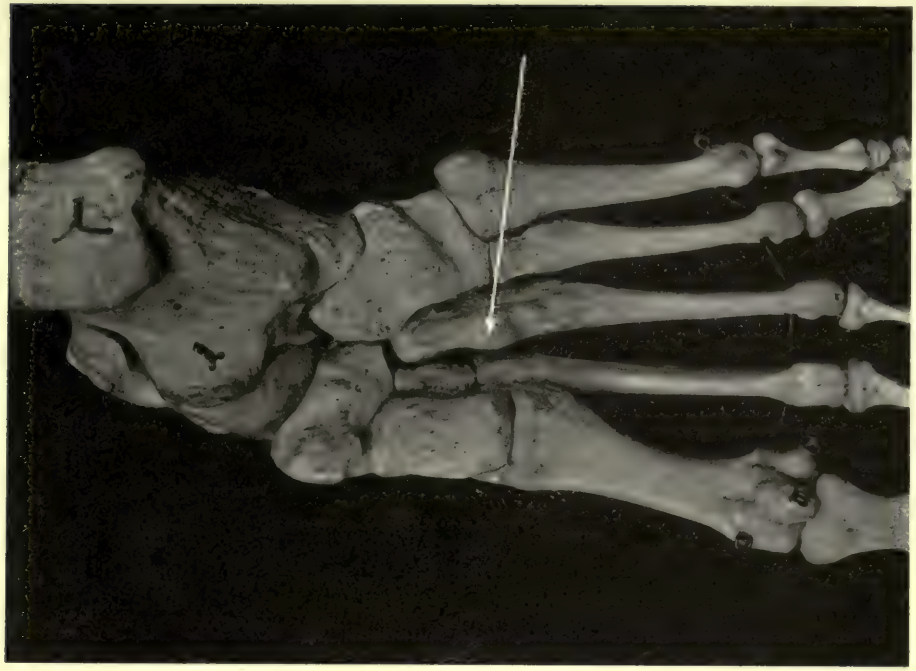

FIG. 73.

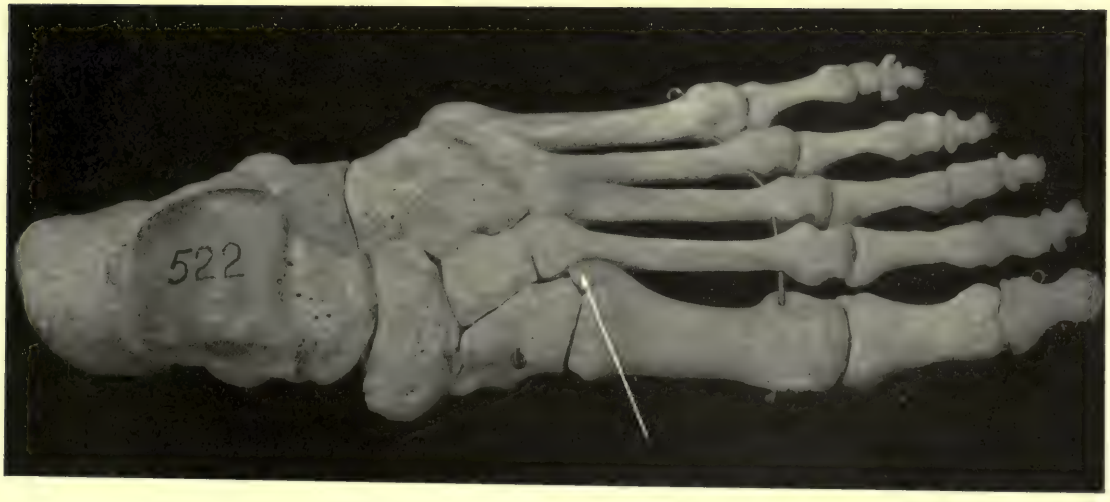

FIG. 72.

PLATE XXXV.

FIG. 74. Varying development of the tuberosity of the fifth metatarsal and of the *Vesalianum*. The latter is very evident on the bone on the left, and presumably not present on the bone on the right.

FIG. 75. *Vesalianum*. An X-ray of the foot of a girl (?) aged 13, showing a separate element very clearly. There is no suspicion of injury, for the skiagraph was taken on account of a bullet wound in another part of the foot. I have placed a question mark after the word "girl" because my record of the sex is lost, but there is very little doubt on the point.

FIG. 74.

FIG. 75.

PLATE XXXVI.

FIG. 76. *Divided internal sesamoid* of great toe. An X-ray of a woman who applied at the Massachusetts General Hospital for lung disease. She had had pain in her foot for five years, but it had grown worse six or seven months before. There were tenderness and grating about the head of the fourth metatarsal. There was no allusion to symptoms about the great toe. There is no reason to doubt that the condition was congenital, especially as the appearance is the typical one and is by no means excessively rare.

FIG. 77. An X-ray of a foot with fusion of the last two phalanges of the little toe. The same condition is found in the foot shown in fig. 36. There is no reason to think it pathological. If looked for it will be found very frequently.

FIG. 78. Suggestion in an X-ray of *four phalanges* in the little toe of a young person. There is a fracture of the three inner metacarpals, but no sign of injury to the fifth. Of course, as is shown in the text, the suggestion is a false one.

FIG. 79. *Ditto.* In this foot there is no suspicion of injury.

PLATE XXXVI.

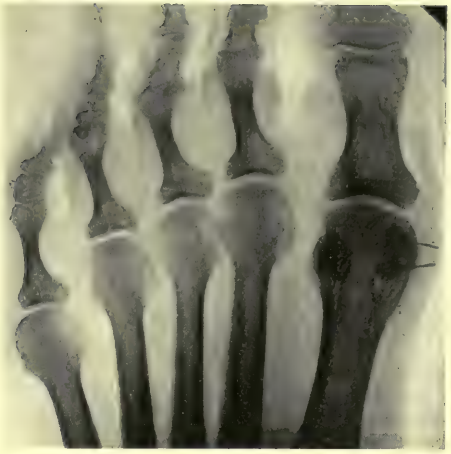

FIG. 76.

FIG. 77.

FIG. 78.

FIG. 79.

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